Quantum Sensors, Devices and Materials

Baltic-German WE-Heraeus-Seminar

15 - 18 March 2026

at the Physikzentrum Bad Honnef, Germany

WILHELM UND ELSE HERAEUS-STIFTUNG

Introduction

The Wilhelm und Else Heraeus-Stiftung is a private foundation that supports research and education in science with an emphasis on physics. It is recognized as Germany's most important private institution funding physics. Some of the activities of the foundation are carried out in close cooperation with the German Physical Society (Deutsche Physikalische Gesellschaft). For detailed information see https://www.we-heraeus-stiftung.de

Aims and scope of the Baltic-German WE-Heraeus-Seminar:

Active research collaboration between German and Latvian scientists currently spans a number of exciting research areas of quantum science and technology including single-electron nanoelectronics, novel 2D materials, quantum magnetometry with levitated, atomic, and colour - centre magnets, and single-photon emitters among others. This Workshop will bring together representatives of the diverse research communities with a goal of fostering cross-topic "fertilization" and strengthening and broadening the bi-national cooperation, as well as expanding international collaboration beyond the two nations, in particular to the Baltic scene on synergetic topics. The workshop, open to international participation beyond Baltics and Germany, will feature overview talks by top experts in the respective fields, contributed talks and posters, and plentiful opportunities for informal interactions in a beautiful setting of the Bad Honnef Physics Center.

Introduction

Scientific Organizers:

Prof. Dr. Dmitry Budker	Helmholz Institute University Mainz, Germany
PD Dr. Frank Hohls	Physikalisch-Technische Bundesanstalt Braunschweig, Germany
Dr. Gunta Kunakova	Institute of Chemical Physics University of Latvia
Prof. Dr. Vyacheslavs Kashcheyevs	Department of Physics University of Latvia

Administrative Organization:

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Introduction

Venue:

Physikzentrum
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Registration:

Nadine Mock (WE Heraeus Foundation)
at the Physikzentrum, reception office
Sunday (17:00 h – 21:00 h) and Monday morning

Program

Program

Sunday, 15 March 2026

17:00 - 21:00	Registration	
18:15 - 19:45	*BUFFET SUPPER and informal get-together*	
19:45 - 20:00	**Greetings from organizers**	
20:00 - 20:45	Florian Gahbauer	**Another kind of cryogenics: physics in Antarctica**

Program

Monday, 16 March 2026

07:30 - 08:45	*BREAKFAST*	
08:45 - 09:30	Chris Bauerle	**Fundamental science & quantum technology using flying electrons**
09:30 - 10:15	Andrey Surzhykov	**Atomic magnetometry with vector light**
10:15 - 10:45	*COFFEE BREAK*	
10:45 - 11:30	Ferdinand Kuemmeth	**Superconducting germanium quantum dots**
11:30 - 12:00	Victor Adam	**Coherent Two-Qubit Control in Industrial Si/SiGe Spin Qubits**
12:00 - 12:20	Thomas Gerster	**Quantum Technologies Standardization: Standards as Key to Innovation and Industrial Applications**
12:20 - 12:30	CONFERENCE PHOTO (in front of the main entrance)	
12:30 - 14:00	*LUNCH*	
14:00 - 14:45	Angela Wittmann	**Diamond-based magnetic imaging of topological textures**
14:45 - 15:30	Mathias Kläui *(remote)*	**Topological Spin Structures & Spin-Orbitronics in 2D: from van der Waals systems to multilayers**
15:30 - 16:15	Renata Butkute	**Engineering of A3-B5-Bi quantum structures for NIR microlasers: technological challenges and design strategies**

Program

Monday, 16 March 2026

16:15 - 16:45	*COFFEE BREAK*
16:45 - 18:15	**Poster flash talks (1 presentation = 90 s)**
18:15 - 19:45	*DINNER*
19:45 – 21:00	**Poster session**

Program

Tuesday, 17 March 2026

07:30 - 08:45	*BREAKFAST*	
08:45 - 9:30	Charles Gould	**The QAHE as a zero field resistance standard.**
9:30 - 10:15	Chuan Li	**Gate-tunable Josephson diode effect in topological semimetal**
10:15 - 10:45	*COFFEE BREAK*	
10:45 - 11:00	**About the Wilhelm and Else Heraeus Foundation**	
11:00 - 11:45	Raivo Stern	**Spectroscopy of some quantum materials at low temperatures and high applied magnetic fields.**
11:45 - 12:30	Aivars Vembris	**Single photon sources**
12:30 - 14:00	*LUNCH*	
14:00 - 14:45	Hans Werner Schumacher	**Single Elctron Pumps for the new SI system of units**
14:45 - 15:30	Masaya Kataoka	**Scaling-up single-electron pumps**
15:30 - 15:50	Dustin Wittbrodt	**Spin-Qubit Technology for Single Electron Pumps**
15:50 - 16:10	Girts Barinovs	**Birth, Life, and Death of Bound Electron-Pair States in a Two-Dimensional Electron Gas**
16:10 - 16:45	*COFFEE BREAK*	

Program

Tuesday, 17 March 2026

16:45 - 17:30	Vinante Andrea	**Levitated ferromagnets: experimental progress and fundamental physics prospects**
17:30 - 18:30	Dmitry Budker	**Fundamental Physics on a couch, in the lab, in an Elevator, and in Space**
18:30 - 20:30	*HERAEUS-DINNER*	

Program

Wednesday, 18 March 2026

07:30 - 08:45	*BREAKFAST*	
08:45 - 09:30	Gediminas Juzeliūnas	**Two-dimensional topological sub-wavelength lattices for ultracold atoms**
09:30 - 10:15	Franziska Weickert	**Primary Tesla Standards**
10:15 - 10:45	*COFFEE BREAK*	
10:45 - 11:30	Anne Fabricant	**Batteries as a use case for quantum sensing**
11:30 - 12:15	Vyacheslavs Kashcheyevs	**Ballistic electrons in a chip: electron quantum optics with strong non-linearity**
12:15 - 12:30	**Closing remarks**	
12:30 - 14:00	*LUNCH*	

End of the seminar and departure

Posters

Posters

Robin Abram	**Height Calibration of Nitrogen Vacancy Diamond Tips Using Current-Carrying Wires**
Christopher Barker	**Thermoelectric fingerprinting of Bloch- and Néel-type skyrmions**
Johannes C. Bayer	**GaAs quantum dots for single-electron current sources**
Yarne Beerden	**Assessing the effects of space radiation on quantum diamond sensor performance**
Ifra Bibi	**Laser-Based Creation of Room-Temperature Quantum Emitters in Hexagonal Boron Nitride**
Alberts Bilzens	**Modelling of a Shallow Elliptic Quantum Dot in a Transverse Magnetic Field**
Mark Blumenthal	**Landau level single-electron pumping**
Domantas Burba	**Pair and chiral superfluidity in subwavelength triangular ladders**
Edgars Butanovs	**Thin amorphous molybdenum silicide superconducting shells around individual nanowires deposited via magnetron co-sputtering**
Nathan Deveux	**SRIM calculations of ion implantation in diamond for membrane fabrication**
Nishant Dogra	**From Quantum Sensing to teaching Quantum with NV Centers**
Mylo Gijbels	**Temperature sensing using double quantum resonance of Nitrogen-Vacancy centers in diamond**
Christopher Habenschaden	**Enhancing Quantitative Magnetic Force Microscopy through NV Calibration**

Posters

Göran Hellmann	**Crosstalk compensation for an Mx magnetometer-based gradiometer**
Emma Herbst	**In-situ Detection of Free Radicals using NV Center-based T1 Relaxometry**
Mona Jani	**Microwave-Free Detection and Imaging of magnetic nanostructures using fluorescent nanodiamond**
Alnis Janis	**Research on optical whispering gallery mode micro-resonators**
Aris Jansons	**Perhydropolysilazane as a Scalable Gate Dielectric for 2D WTe_2 Based Electronics**
Karina Korenika	**Determination of relative transition probabilities of atomic niobium derived from Fourier transform spectra**
Valts Krumins	**Field-gradient spectroscopy of Rydberg positronium in a strong magnetic field**
Reinis Lazda	**A compact NV diamond magnetometer for contactless current monitoring and low-frequency magnetic communication**
Martin Lee	**Towards in-situ Twistronics using the Quantum Twisting Microscope**
Matthias Ludwig	**Photonic integrated top-hat beam profiler for multi-ion clock application**
Hendrik Mannel	**Near transform-limited single photons from rapid-thermal annealed quantum dots**
Marco Antonio Manya Suni	**Optimal Observables and NMR sensors**
Arturs Mozers	**Exploring nonlinear-Zeeman-effect-free magneto-optical signals from high-order coherences in atomic Rb**

Posters

Kiryl Niherysh	**Chiral Anomaly-Driven Quantum Transport in Tellurium Weyl Semiconductor Nanoribbons**
Antons Nikolajevs	**Floquet-theory-based description of single- and double-photon Autler-Townes effect with radiofrequency excitation of Cs atoms**
Muhib Omar	**NV center gyroscope at zero field**
Elina Pavlovska	**Mesoscopic Coulomb collisions of on-demand electrons**
Ivan Petrov	**Three NV centers with dipole-dipole coupling as a quantum register**
Ignas Pikas	**UV mirrors with enchanted Optical Phase Shift control using combination of standard and structural coatings**
Anna Veronika Priede	**Temperature-Induced Zero-Field Splitting Error Suppression in NV-Centre Vector Magnetometry Beyond the Axial Approximation**
Juris Prikulis	**Self-organized hybrid nanostructure arrays for optical sensing**
Eugenia Pyurbeeva	**Entropy in nanodevices — a source of insight and control**
Torsten Roeper	**Propagation, dissipation, and breakdown of high-frequency edge state transport in a quantum anomalous Hall insulator**
Oskars Rudzitis	**Quantum Random Number Generation Using Nitrogen-Vacancy Centers in Diamond**
Theo Scholtes	**Fabrication of atomic vapour cells by laser-assisted bonding**
Daniel Schroller	**Industrial Silicon Metal-Oxide-Semiconductor Spin Qubits as Quantum Sensors for Single-Molecule Magnet Qudits**
Vakaris Silys	**Optimization of magnetic-field quantum sensing with NV centers**

Posters

Andreas Sinner	**Designing Moiré Patterns by Strain**
Agnese Spustaka	**WTe_2 heterostructures for studies of unconventional edge states**
Ralfs Suba	**Monte Carlo simulation of partitioning statistics of a one component Coulomb plasma**
Jeļena Sušinska	**Tellurium-based 1D Nanostructures: Synthesis, Structure and Electrical Transport**
Asli Tuncer	**Disorder as a Resource: Spin-Glass Quantum Otto Engines for Disorder-Resilient Quantum Devices**
Sebastian Westrich	**FRET between NV centers in diamond and chlorophyll molecules: a novel resource for multimodal sensing and imaging in plant cells**
Florian Wittkaemper	**Tailored functionalized microfabricated alkali vapour cells**
Chelsey Zhang	**Metrological Evaluation of Gas Sensing in Printed 2D Transition Metal Dichalcogenide Films**

Abstracts of Talks

(in alphabetical order)

Coherent Two-Qubit Control in Industrial Si/SiGe Spin Qubits

Viktor Adam[1] and **Wolfgang Wernsdorfer[1]**

[1]*IQMT (KIT), Karlsruhe, Germany*

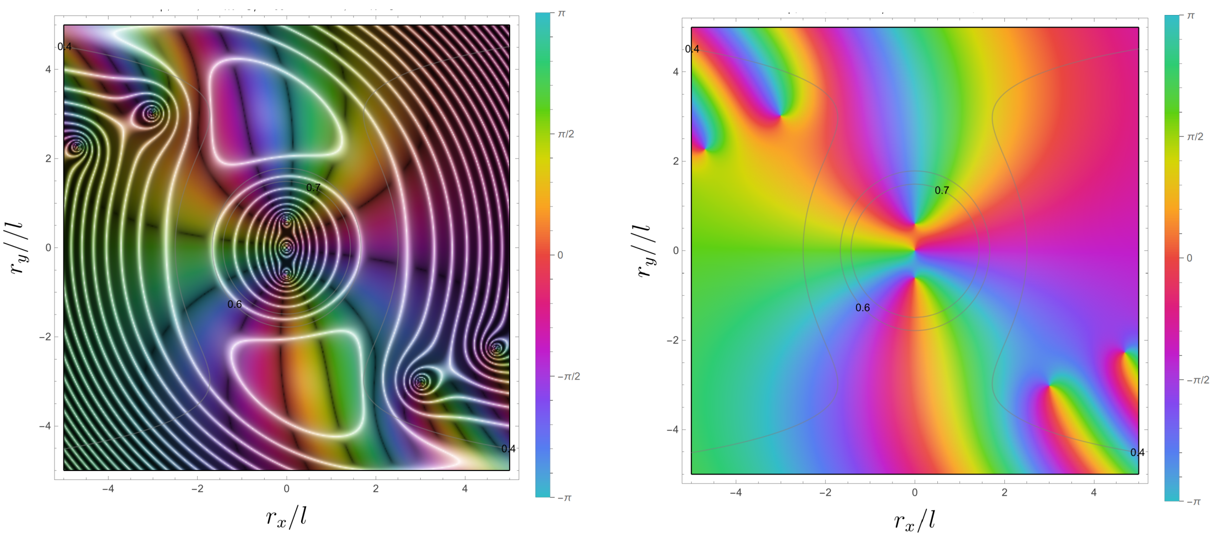
This talk demonstrates coherent single- and two-qubit operations using Si/SiGe spin qubit devices fabricated by imec (Interuniversity Microelectronics Centre) entirely in an industrial fabrication line, including monolithic integration of cobalt micromagnets for spin control. Two individual qubits were formed and coherently driven in the MHz range, exhibiting Ramsey coherence times exceeding 1 µs, and Hahn-echo times of up to 79 µs, primarily limited by nuclear spin noise from naturally abundant ^{29}Si isotopes. These values confirm robust coherence in an industrial platform, with differences in between both qubits attributed to spatial proximity to decoherence sources. Two-qubit logic was realized by inducing exchange coupling in a double quantum dot, achieving interaction strengths of up to 20 MHz. Conditional resonance shifts under finite coupling confirmed coherent spin-spin interactions and enabled implementation of the conditional rotation (CROT) gate. Coherent two-qubit dynamics were observed in both time and frequency domains, validating functional entangling operations. These results validate that industrially fabricated Si-based spin qubits can meet the stringent requirements for coherent multi-qubit operation, supporting silicon spin qubits as a viable architecture for universal quantum computation.

Birth, Life, and Death of Bound Electron-Pair States in a Two-Dimensional Electron Gas

G. Barinovs, A. Buzs, V. Kashcheyevs

Department of Physics, University of Latvia, Riga, LV-1004, Latvia

Two-electron pair states in a free two-dimensional electron gas remain stable in the presence of a transverse magnetic field. An external confining electric potential at an edge or at a quantum point contact not only modifies the pair energies but also triggers pair breakup. We present a theoretical model that captures the effect of external perturbations on the energies and stability of electron-pair states, and we numerically calculate the corresponding pair wave functions. The theoretical description is based on perturbation theory and WKB approximation, and the approximations are validated using complex scaling of coordinates and time evolution with the split-step propagator method. Our analysis indicates that, for typical two-dimensional devices, magnetic fields are strong enough for two-electron pairs to form and survive over experimentally relevant timescales. We demonstrate in a time-dependent wave-packet calculation the creation and decay of a bound two-electron pair during a collision of two electrons at a saddle-point potential in a Hong–Ou–Mandel interferometer setup. We show and explain how, both during wave-packet evolution and in the bound two-electron pair state, the probability density in the inter-electronic coordinate is governed and dominated by its zeros.



Probability density shown by white contour lines on a logarithmic scale and wave-function phase encoded by colour, dominated by zeros for a decaying electron pair state at an edge, as a function of inter-electron relative coordinate r scaled by magnetic length l.

Basic Science & Quantum Technology using flying electrons

Christopher Bäuerle

Néel Institute, CNRS Grenoble, France

Decades of intensive research have focused on the precise control of single electrons, a key requirement for establishing the electrical current standard in the SI unit system. More recently, the concept of flying electron qubits has emerged: here, the charge or spin degree of freedom of an electron serves as a qubit, which can be manipulated and transported through electronic circuits using simple electromagnetic fields [1]. Despite the progress, significant challenges remain, particularly in achieving high-fidelity control and scalable quantum circuit design.
In this talk, I will provide an overview of our research over the past years, which includes high-fidelity transport of single electrons using surface acoustic waves, as well as controlled collision experiments between two electrons [2] that reveal extremely strong Coulomb interactions—interactions that can be directly harnessed for quantum technologies.
On a more fundamental note, I will show how precise control over the number of electrons in on-chip collision experiments allows us to probe the system's phase diagram. By drawing analogies with heavy-ion collider experiments, we can demonstrate that even a droplet of just three electrons behaves as a correlated state—a Coulomb liquid [3].
In the second part of my talk, I will present a complementary approach to flying electron qubits using ultrashort electron wave packets generated within the Fermi sea. Compared to DC injection, this method enhances coherence, opening the door to a wide range of single-electron quantum experiments [4] and advancing both quantum information processing and our understanding of nanoscale quantum phenomena.

References

[1] C. Bäuerle et al., Reports on Progress in Physics **81**, 056503 (2018)
[2] J. Wang et al., Nature Nanotechnology **18**, 721 (2023)
[3] J. Shaju et al., Nature **642**, 928–933 (2025
[4] S. Ouacel et al., Nature Communications **16** 4632 (2025).

Engineering of A3-B5-Bi quantum structures for NIR microlasers: technological challenges and design strategies

A.Špokas, A. Zelioli, R. Butkutė

Center for Physical Sciences and Technology, Vilnius, Lithuania

Near infrared (NIR) starting from 1000 nm to 1550 nm has become a crucially important wavelength region in a wide area of applications: sensing systems, medical procedures, quantum communications, etc. [1]. These fields require semiconductor laser sources with varying sizes, powers and designs. The current photonics market offers standard low cost, reliable and compact electrically injected edge-emitting laser diodes (LD), which have become irreplaceable for optical communications. However, standard emitters suffer from the losses due to non-radiative Auger recombination. On the other hand, quantum communications require much higher beam quality, greater output powers while still maintaining wavelength versatility what can be achieved by optical pumping of vertical external cavity surface emitting laser (VECSEL) [2].

The material selection in this region is not straight forward, while some materials like InGaAs and InGaAsP are commercially successful. They progress is held back by losses linked to the inherent features of these alloys and inefficient operation due to the necessity of cooling. Thus, the described situation and intensive progress in photonics sector stimulates development of sources containing different semiconductor compounds.

This work addresses the study of a relatively new semiconductor - bismide, GaAsBi, proposed as an alternative, that could overcome some limits with its stable room-temperature operation and ability to suppress Auger loses. The most attractive advantage of bismide is based on its two unique features: the first, fast reduction of the energy bandgap due to the substitution of fifth-group As atoms by Bi, and the second, several times higher temperature stability of the bandgap. However, the success of application is held back by complex growth conditions (*T*growth <400˚C and nearly stoichiometric As_2 and Ga flux ratios, necessary for Bi introduction), which promote the formation of various defects (antisites, clusters, phase separation, dislocations). Consequently, to create effective NIR sources and improve their performance the enhancement of the crystal and optical quality of GaAsBi through optimization of technology and understanding of radiative recombination mechanisms is necessary.

References

[1] P. Dnyaneshwar, *Semiconductor Laser Diode Technology and Applications,* Ed. 2012, InTech.

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Batteries as a use case for quantum sensing

A. Fabricant
Department of Biosignals, Physikalisch-Technische Bundesanstalt (PTB) Berlin, Germany

As one of the pillars of quantum technologies, quantum sensing is often overshadowed by its “flashier” cousins, quantum computing and communication. However, quantum sensing, especially magnetic sensing, is arguably poised to have the greatest real-world reach. As an example of this, my talk will focus on the use of atomic optically pumped magnetometers (OPMs) for the characterization of lithium-ion batteries relevant for electric vehicles. I will highlight three experimental directions: (1) magnetic imaging of current density during dynamic battery processes as well as in open-circuit configuration [1], (2) chemical fingerprinting of electrolyte inside battery housing via ultralow-field nuclear-magnetic-resonance (ULF-NMR) spectroscopy [2], and (3) development of comparative methodology for integrating OPM-based imaging with conventional diagnostic methods such as electrochemical impedance spectroscopy (EIS) and calorimetry. Recurring themes throughout this work include the development of customized OPM sensors as well as benchmarking measurements using superconducting-quantum-interference-device (SQUID) magnetometers. Beyond proof of principle, the larger aim of quantum magnetometry for battery testing is to achieve technology transfer to industrially relevant applications in battery production and recycling (second-life assessment), by enabling rapid noninvasive and spatially resolved detection of defects and aging mechanisms.

References

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Another kind of cryogenics: physics in Antarctica

<u>F. Gahbauer</u>[1,2] for the GAPS collaboration

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While attempting to unlock the secrets of nature, physicists sometimes have to leave the comfort of their laboratories. The search for evidence of dark matter in cosmic rays is one such instance. Direct-detection dark matter searches usually are conducted underground, mainly to avoid interference from cosmic rays. Indirect dark-matter searches look at signals in the cosmic rays, which are noise for the direct-detection experiments, but could be the sign of significant new physics. If WIMPS (weakly interacting massive particles) make up dark matter, their collisions would produce low-energy anti-deuterons in cosmic rays. The flux of anti-deuterons is kinematically suppressed at low energies, meaning that very few are produced naturally, and the background noise is orders of magnitude lower than the potential signal from realistic dark-matter models [1]. Therefore, observing even a single low-energy anti-deuteron would be a clear and strong indication of WIMP dark matter.

To detect such rare events or to meaningfully constrain the possible properties of dark matter, researchers need to conduct long-term observations with large detectors in regions where low-energy charged particles can penetrate the Earth's magnetic field. High latitudes, such as Antarctica, are ideal for this purpose. All these conditions can be met by flying particle detectors suspended from scientific balloons in Antarctica. Based on my experience with the GAPS experiment (General AntiParticle Spectrometer) [2]—a multi-national collaboration led by Columbia University—I will present the unique challenges of conducting physics research in Antarctica using a balloon platform, and introduce the detection approach of the GAPS instrument, which was launched on December 16, 2025 from McMurdo Station, Antarctica.

References

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[2] T. Aramaki et al., Astroparticle Physics 74, 6 (2016)

Quantum Technologies Standardization: Standards as Key to Innovation and Industrial Applications

T. Gerster

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The standardization of quantum technologies is a key element for a successful technology transfer from research labs to a future global market with worldwide supply chains. From a European perspective it needs to be started at an early stage to strongly support this development and address Europe's economic and strategic interests in this emerging, worldwide market.

Following the recommendation of the 2023 FGQT Roadmap, a Joint Technical Committee for Quantum Technologies (JTC22) was successfully established by CEN/CENELEC [1], enabling all 34 CEN/CLC member nations to participate in the European, harmonized standardization efforts for quantum technologies [2]. In this talk, I will give an overview on this standardization committee and recent work items in the field of quantum metrology, - sensing, and enabling technologies. This covers technical topics like color centers, ion traps, travelling wave parametric amplifiers, single electron devices, gravimeters and others.

National Metrology Institutes (NMIs) strongly contribute to these efforts by their long-term experience in investigating and applying quantum effects for metrology in general [3]. Moreover, the NMIs are highly relevant to develop and build up a globally accepted, independent measurement and testing infrastructure for quantum technologies directly referred to these newly developed standards [4,5]. Consensus standards development is contribution driven by equally academia and industry, especially in an emerging high-tech field like quantum technologies. Joint work on European standards can help to accelerate the transfer from research into applications, deepen the relationships between academia and industry, and strengthen the European position in a global market.

References

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A new quantum standard of resistance

Kajetan M. Fijalkowski[2,3], Dinesh K. Patel[1], Mattias Kruskopf[1], Nan Liu[2,3], Martin Götz[1], Eckart Pesel[1], Marcelo Jaime[1], Martin Klement[2,3], Steffen Schreyeck[2,3], Karl Brunner[2,3], Charles Gould[2,3], Laurens W. Molenkamp[2,3] and Hansjörg Scherer[1]

[1] *Physikalisch-Technische Bundesanstalt (PTB), Braunschweig, Germany.*
[2] *Faculty for Physics and Astronomy (EP3), Universität Würzburg, Würzburg, Germany*
[3] *Institute for Topological Insulators (ITI), Würzburg, Germany*

The quantum anomalous Hall effect (QAHE), first observed in a magnetic topological insulator Cr/V-doped $(Bi,Sb)_2Te_3$ [1], holds promise as a disruptive innovation in quantum metrology, for its potential to define a new generation of quantum standards of resistance [2,3]. Indeed, one of the goals of modern metrology is to combine various standards into a so-called quantum electrical metrology toolbox, a single measurement apparatus that can perform quantum resistance, voltage and current metrology, *i.e.* a universal electrical standard. Conventional quantum standards of resistance rely on the integer quantum Hall effect. The large external magnetic field needed to establish the quantum Hall effect makes a quantum standard of voltage (based on the a.c. Josephson effect) inoperable [4]. This is where QAHE can save the day and enable combined standards by providing resistance quantization at zero external magnetic field [3]. This is also important in the context of the recent redefinition of the SI system, as the unit of mass, the kilogram, is now defined based on the Planck's constant (h). With values e and h also being defined in the revised SI, also the values of the von-Klitzing (h/e^2) and Josephson ($2e/h$) constants are defined and enable primary realizations of the ohm and the volt. A simultaneous realization of both quantum standards in a single cryostat (setup) bears benefits for experiments like the Kibble balance, which needs the combination of both quantum standards.

Here I will discuss our recent realization of a zero external magnetic field quantum standard of resistance using the QAHE, with a relative quantization precision and accuracy of a few parts-per-billion (or 10^{-9}) [3], for the first time surpassing the relevant thresholds for a quantum resistance standard. While demonstrating that the effect can indeed be used in metrology, this was realized under very challenging experimental conditions (extremely low temperature and low electrical current). The effect will need to be made significantly more robust to enable mainstream metrology applications, and I will show why our recent results give us confidence this is possible [5,6].

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Two-dimensional topological sub-wavelength lattices for ultracold atoms

Domantas Burba and Gediminas Juzeliūnas

Institute of Theoretical Physics and Astronomy, Department of Physics,

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Ultracold atoms provide a versatile platform for quantum sensing, as well as for simulating topological and many-body phenomena in condensed matter and high-energy physics [1-3]. The use of atomic dark states (long-lived superpositions of atomic internal ground states immune to atom-light coupling) offers new possibilities for such simulations. Making the dark states position-dependent allows for the generation of a synthetic magnetic field for ultracold atoms, which adiabatically follow the dark states [4]. Recently, two-dimensional (2D) dark-state lattices have been considered [5-7].

Here, we present a general description of 2D topological dark state lattices elucidating an interplay with the sub-wavelength lattices [6]. In particular, we demonstrate that one can create a 2D Kronig-Penney lattice representing a periodic set of 2D subwavelength potential peaks affected by a non-staggered magnetic flux. Away from these patches of the strong magnetic field, there is a smooth background magnetic flux of the opposite sign, compensating for the former peaks. While the total magnetic flux is zero, the system supports topological phases due to the flux variation over a unit cell, similar to Haldane-type lattice models with zero net flux over an elementary cell, but with non-trivial topology due to non-zero fluxes over the plaquettes that constitute the elementary cell. This work paves the way for experimental exploration of topological phases in dark-state optical lattices, offering new possibilities for simulating quantum Hall systems, fractional Chern insulators and related strongly correlated phases.

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Ballistic electrons in a chip: electron quantum optics with strong non-linearity

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Universality of electrical charge quantization and the fundamental nature of the Planck constant are the foundational principles of electrical quantum metrology where macroscopic quantum phenomena (quantum Hall and Josephson effects) are routinely employed in commercial high-precision measurements systems. Here we argue that more recent advances in high-fidelity manipulation of discrete electrons for metrological current sources open up a new resource for quantum technologies 2.0 [1-3] with individual electrons propagating in semiconductor circuits in direct analogy to photons. We discuss an electron quantum optics toolbox of circuit elements for on-demand emission, transformation, and read-out of single-electron wave-packets, emphasizing the unique advantages of beamsplitters [2] with the dispersion tuneable by the field effect and the non-linearity mediated by controlled Coulomb interaction. Envisioned applications are quantum-limited sensors for picosecond scale electrical signals and eventually an all-electronic quantum information platform interfaceable with other cryogenic on-chip technologies.

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Scaling-up single-electron pumps

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Scaling-up the number of nano-scale devices on chip is a challenge that needs to be overcome in order for the applications of integrated quantum devices [1] to be realised. Even at an early stage of development, scaling can be useful in performing statistical study for the purpose of improving the device performance [2]. Single-electron pumps [3] based on semiconductor quantum dots could benefit from such scaling technologies, in terms of both increasing the generated current and improving the current-quantisation accuracy. The current scaling by increasing the operation frequency is hitting the limit in achieving the required accuracy [4,5], and further scaling may benefit from the parallelisation [6] of a large number of pumps.

Here, we will present our recent development of multiplexed single-electron pump devices based on GaAs heterostructures. We demonstrate the operation of 64 single-electron pumps on chip with 6-bit multiplexer [7], and the method of accelerating device characterization using a machine-learning technique [8]. We will also further discuss how these scaling techniques could be used for other applications, such as electron quantum optics [9] and single-photon emitters [10].

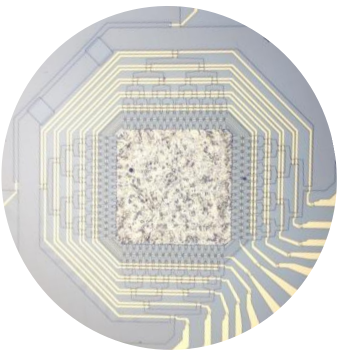

Fig. 1. Six-bit multiplexer single-electron pumps.

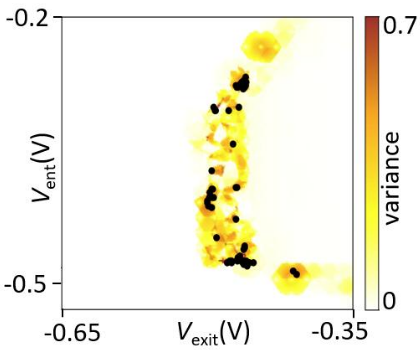

Fig. 2. Parameter hotspots in active learning measurement.

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Topological Spin Structures & Spin-Orbitronics in 2D: from van der Waals systems to multilayers

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Novel spintronic devices can play a role in the quest for GreenIT if they are stable and can transport and manipulate spin with low power. Devices have been proposed, where switching by energy-efficient approaches is used to manipulate topological spin structures that are stable in multilayers [1] but also in 2D van der Waals systems [2].
We combine ultimate stability of topological states due to chiral interactions [3,4] with ultra-efficient manipulation using novel spin torques [3-5]. In particular orbital torques increase the switching efficiency by more than a factor 10 [6]. Going towards 2D van der Waals systems, we explore bulk spin – orbit torques resulting from the particular symmetry [7]. In such 2D heterostructures of ferromagnets and antiferromagnets, also enhanced exchange bias is observed allowing one to control the switching [8,9].

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Superconducting germanium quantum dots

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Germanium quantum wells can host hard-gapped superconductor-semiconductor interfaces [1]. They can also host spinful quantum dots suitable for quantum information processing via spin-orbit coupling [2]. Can they host spinful superconducting quantum dots?

I will present our work on developing quantum-dot (QD) devices in a Ge/SiGe heterostructure proximitized by superconductor (SC) regions of platinum germanosilicide (PtGeSi), forming gate-tunable SC-QD-SC junctions [3]. Gate control of the QD-SC coupling strength allows us to change the ground state of the system between even and odd parity. We characterize the critical magnetic field strengths and explore sub-gap spin splittings in the Yu-Shiba-Rusinov limit. The demonstration of controllable proximitization at the nanoscale of a germanium quantum dot opens the door towards novel qubit modalities in a group-IV material system.

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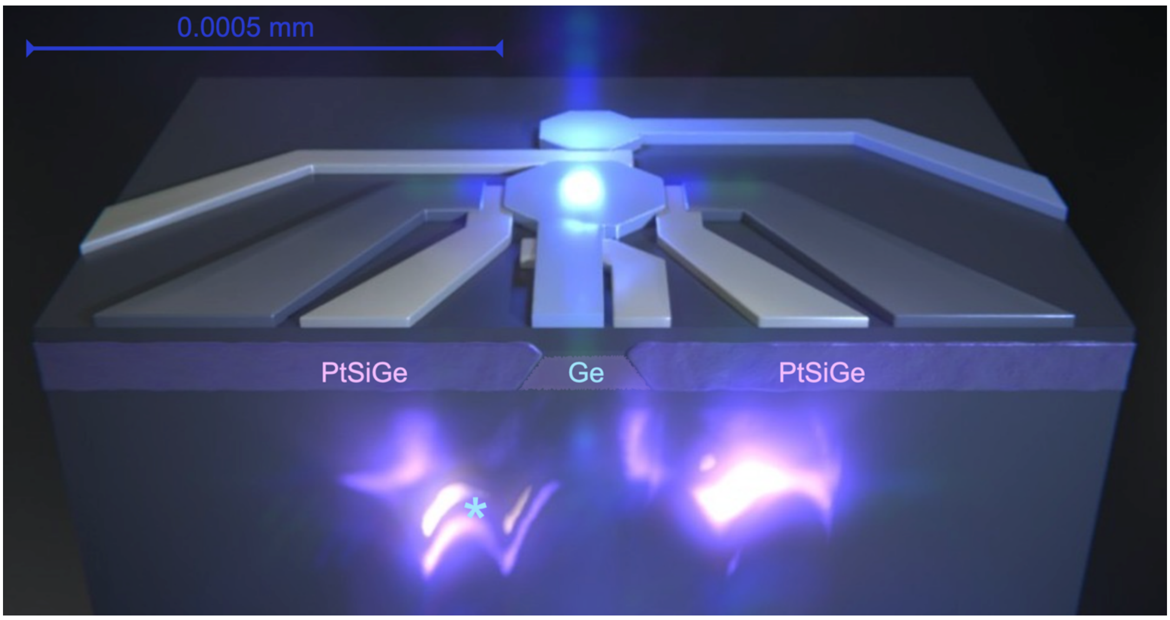

Gate-tunable strongly anisotropic Josephson diode effect in topological Dirac semimetal Cd_3As_2 nanowires

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The intrinsic Josephson diode effect (JDE) has recently attracted considerable attention due to its sensitivity to broken symmetries in Josephson junctions, offering a powerful probe for uncovering hidden symmetry-breaking mechanisms in materials. The presence of higher-harmonic components in the current-phase relation, together with spin-orbital coupling, makes topological materials ideal platforms to explore this effect. In this work, we present a systematic study of the JDE in type-I topological Dirac semimetal Cd$_3$As$_2$ nanowire-based Josephson junctions. We observe a pronounced gate-tunable and highly anisotropic diode response under different magnetic-field orientations. By developing a comprehensive phenomenological model, we capture the angular dependence of the diode effect and, through temperature-dependent measurements, disentangle the respective contributions from bulk and topological surface states [1,2]. Notably, anomalies in the temperature dependence of the diode efficiency reveal the coexistence of multiple transport channels, highlighting the Josephson diode effect as a sensitive probe of hidden topological superconducting states.

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Single electron pumps as quantum current standards for the new SI

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Since 2019, the SI base units are defined by fixed values of a set of fundamental constants, among them the elementary charge *e*. Hence, a direct primary standard for the electrical base unit ampere could be realized by so-called single electron pumps [1]. They are based on single electron transistors that are driven by an oscillating gate voltage with frequency *f*. During one oscillation cycle one electron is first captured from source and later ejected to drain thereby generating a quantized current $I = ef$. In my talk I will review the present state of single electron pumps for the direct representation of the ampere. I will show that semiconductor-based single electron pumps are excellent candidates for primary current standards allowing high enough currents in combination with excellent quantization accuracy [2]. I will further discuss in-situ measurements of pump errors by single charge detection [3] and, if time allows, will give a short outlook on further prospects of single electron pumps like the generation of shot noise free currents or the selection of specific quantum states during the capturing process [4].

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Spectroscopy of some quantum materials at low temperatures and high applied magnetic fields.

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I'll review selected examples of recent spectroscopic studies (NMR and THz) of quantum materials at low temperatures and high applied magnetic fields, performed by researchers from Estonia.

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Atomic magnetometry with vector light

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Over the past few decades, vector light modes have attracted considerable interest across diverse areas of research due to their tailored properties, including highly inhomogeneous intensity distributions, phase singularities, and complex polarization textures. Among other emerging applications, atomic magnetometry stands out as particularly promising [1,2], as vector light enables efficient diagnostics of both the direction and spatial gradients of static as well as time-dependent magnetic fields.

In this presentation, I will review recent advances in vector-light enhanced atomic magnetometry, with a particular emphasis on the underlying theoretical framework. Specifically, we will examine recent theoretical studies of vector light propagation through a warm atomic medium subjected to an external magnetic field [3]. It will be demonstrated how the spatial intensity profile of the transmitted light becomes sensitive to the strength, orientation, and gradients of the external magnetic field, thereby establishing fundamental limits and performance benchmarks for vector magnetometry.

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Single photon sources

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Single photon sources are a cornerstone of modern quantum technologies, enabling applications in quantum communication, quantum computing, quantum metrology, and fundamental tests of quantum mechanics. An ideal single photon source should provide on-demand emission of indistinguishable photons with high purity, brightness, and efficiency, while being compatible with scalable fabrication platforms. In addition, sources capable of generating entangled photon pairs are essential for quantum networking and photonic quantum information processing[1,2].

This talk provides an overview of state-of-the-art single and entangled photon sources based on both inorganic and organic materials, with particular emphasis on their integration into photonic circuits[3]. Comparison of probabilistic and deterministic schemes, highlighting trade-offs in brightness, scalability, and integration complexity will be covered.

In the inorganic domain, we discuss solid-state quantum emitters such as semiconductor quantum dots, color centers in wide-bandgap materials (including nitrogen-vacancy and defects in silicon carbide), and epitaxially grown nanostructures[4,5]. Organic single photon sources, including individual molecules embedded in crystalline or polymer hosts, are also examined. Organic emitters are attractive due to their narrow optical transitions at cryogenic temperatures, chemical tunability, and compatibility with large-area and low-cost fabrication techniques[6,7]. Recent progress in stabilizing organic emitters and improving their photostability has enabled their use as reliable single photon sources and also sources of entangled photons.

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Levitated ferromagnets: experimental progress and fundamental physics prospects

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I will present our experimental work on the rotational dynamics of ferromagnetic microspheres levitated via the Meissner effect in a superconducting trap. These systems provide a powerful new platform for precision measurements, thanks to a unique combination of ultralow dissipation and cryogenic temperatures that suppress thermal noise to very low levels. We have investigated three regimes of rotational motion: librational (pendulum-like), gyroscopic and free-spinning. In the librational regime we have demonstrated magnetometry surpassing the Energy Resolution Limit [1], meaning that, for a given sensor volume, we can detect magnetic fields with resolution better than most conventional quantum limited magnetometers. For sufficiently weak angular confinement, a ferromagnet is predicted to behave as an intrinsic gyroscope, with motion dominated by gyromagnetism. This unique regime, first conjectured by Maxwell in 1861, has been recently suggested as a route towards ultrasensitive atomic-like magnetometry [2]. We have recently shown the first hint of gyroscopic dynamics [3] by detecting elliptical trajectories in the free librations of the ferromagnet. Finally, we have realized the free-spinning regime by implementing a synchronous driving technique. The free spin-down of the magnet features sub-mHz dissipation rate at MHz frequencies, corresponding to an ultrahigh quality factor exceeding 10^{13} [4]. In the near term, we believe this is the most promising regime for precision measurements. I will discuss some examples relevant to fundamental physics, such as axionlike dark matter, high frequency gravitational waves and tests of spontaneous collapse models.

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Primary Tesla Standards

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The talk gives an overview on the primary Tesla standard at the German metrology institute PTB as disseminated along traceability chains to stakeholders, industry and end-users. We will present long established methods and show new developments.

Currently, the primary Tesla standard is realized by nuclear magnetic resonance (NMR) techniques on protons with nuclear spin I = ½. The Larmor frequency of the spin precession $\omega_L = \gamma * B$ in a magnetic field is directly proportional to the magnetic flux density B. The proton gyromagnetic ratio γ is known with one part in 10^8 precision from particle-physics experiments [1] and it traces the unit Tesla back to the SI standard time (t). Traceable calibration services are carried out at PTB in the range of 10µT to 0.3T. The method of free induction decay (FID) on pure water samples is used between 10µT and 2mT reaching lowest measurement uncertainties (MUs) of one part in 10^6 (1 ppm) at around 1mT [2]. At higher fields between 1mT and 0.3T, a NMR absorption technique [3] is utilized. Here, the NMR resonance frequency of an LC circuit is measured by means of a marginal oscillator. Samples of aqueous $CuSO_4$ solution enhance NMR absorption rates for a reasonable signal to noise ratio, however, $CuSO_4$ impurities also cause a systematic field distortion, which adds parasitic contributions to the measured magnetic field value. The accuracy of the absorption method is therefore limited to 100ppm.

Furthermore, we will present results on NMR measurements taken on gaseous ^{3}He samples that have an I = ½ nuclear spin as well but exhibit significantly enhanced relaxation times compared to proton spins. Larger relaxation times combined with smaller chemical shift and less temperature dependence reduce the level of MUs for magnetic field measurements on ^{3}He samples. Additionally, hyperpolarization opens the road for a larger field range of the primary Tesla standard at both ends: above 0.3T and below 10µT.

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Spin-Qubit Technology for Single Electron Pumps

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The main workhorse of low current Ampere realization is the Single Electron Pump (SEP), which generates quantized currents based on the quantized transport of single charges. The resulting currents are in the fA-pA range, with a precision of as low as 0.2 ppm [1]. For further improvement of accuracy and current output, parallelization of pumps is necessary. A possible solution is in the form of semiconductor spin qubit devices. In addition to sharing the same central building unit, the quantum dots, spin qubits also offer the possibility of incorporating CMOS logic and taking advantage of a mature, high-yield industry for SEP manufacturing, thus allowing for the implementation of a high number of pumps with minimal control inputs. Various Si [2] and Si-compound [3] spin qubit technology platforms are being tested as SEP candidates, within the EU-funded AQuanTEC project, with a focus on their accuracy and electron pumping behaviour. To benchmark their accuracy, a series of DC measurements is conducted prior to benchmarking the AC modulated pumping regime. We present the results of this effort here, offering a perspective on the potential application of Qubit technology for broader use as quantum metrological instruments.

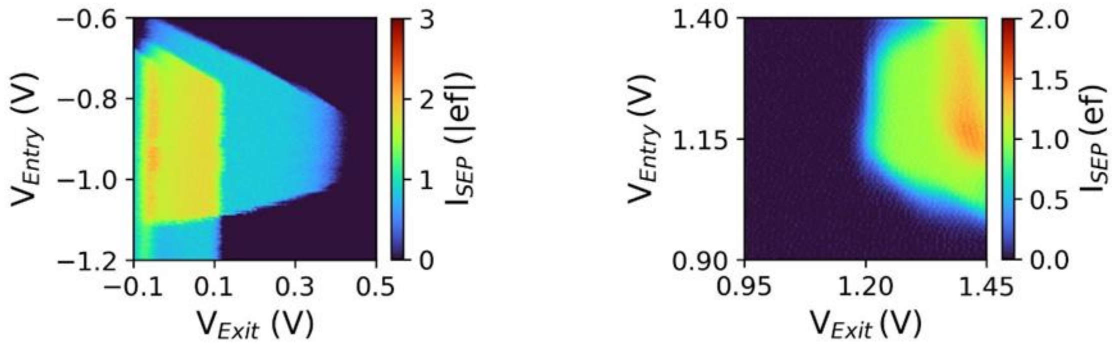

Fig left: Hole pump map in Si-Mos Qubit Devices. Fig right: Electron pump map in SiGe Qubit Devices.

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Diamond-based magnetic imaging of topological magentic textures

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Compensated unconventional magnets such as altermagnets are at the forefront of research in spintronics and demonstrate high potential for revolutionizing memory technologies. However, many of the underlying phenomena for the formation of the domain structure and especially the stabilization of complex textures remain to be explored. In this work, we use magnetic imaging based on a combination of diamond-based scanning nitrogen vacancy center magnetometry and x-ray magnetic dichroism to probe the domain state of unconventional compensated collinear magnetic thin films. Using this complementary approach, we find a variety of topological magentic textures [1]. Unlike in ferromagnetic systems, their stabilization is not predominantly driven by magneto-static or antisymmetric exchange interactions but of magneto-elastic origin [2]. The insights gained from our work serve as a foundation for future studies of electrical and optical manipulation of the domain structure of compensated unconventional magnetic systems paving the way for next-generation magnetic technologies.

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Abstracts of Posters

(in alphabetical order)

Height Calibration of Nitrogen Vacancy Diamond Tips Using Current-Carrying Wires

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Scanning Nitrogen Vacancy Microscopy (SNVM) is a measurement technique capable of resolving the spatial distribution of magnetic stray fields with nanometer and microtesla resolution, respectively [1]. It combines optical field detection with a scanning probe-like approach, where the key component is a diamond scanning tip containing a single NV center [2,3].

While magnetic field measurements are quantum-calibrated with respect to the position of the NV center, precise knowledge of the distance to the sample is required to also consider the height dependence. The latter can currently only be estimated with an uncertainty of up to several nanometers, most commonly by calibration with a known stray field, e.g. using ferromagnetic microstructures [4].

We established an improved height calibration based on SNVM studies of the current-induced Oersted field in Pt wires [5]. The out of plane field component is extracted from the raw data taken along the NV spin axis, following the approach first introduced in [6] and later applied to SNVM in [7], and fitted to an analytical model. Using this approach, we realized a height calibration with an uncertainty of 10 nanometers for both 100 and 111 cut diamond tips. We also found that the nominally expected NV height underestimates the calibration result by about 30 nanometers.

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Thermoelectric fingerprinting of Bloch- and Néel-type skyrmions

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Magnetic skyrmions are nanoscale topologically stabilised spin textures that occur in magnetic thin films due to the interplay of exchange, anisotropy and the Dzyaloshinskii-Moriya interaction (DMI). Their thermal and electrical transport properties make them promising candidates in a range of future computing technologies [1]. Local variations in the skyrmion's spin texture play an important role in skyrmion dynamics; interactions; and response to external stimuli like external fields, electric currents, and thermal gradients [2]. Recently, scanning thermoelectric microscopy (SThEM) has emerged as a powerful technique to map various local thermoelectric and thermomagnetic responses with nanometer resolution [3]. This allows a direct investigation of the coupling between spin textures and thermal gradients. In our recently published work [4], we use SThEM to map the local thermoelectric response of a single skyrmion, giving insight into the fundamental effects that govern skyrmion thermoelectric effects at the nanoscale. By combining our work with modelling, we show that this thermoelectric response can be used to fingerprint the two types of skyrmions: Bloch and Néel. These findings provide the foundations to ascertain the local magnetization of topological spin textures using a generic lab-based scanning probe microscope, and, more fundamentally, offer a route to explore thermally driven charge, spin and magnon transport of complex magnetic spin textures

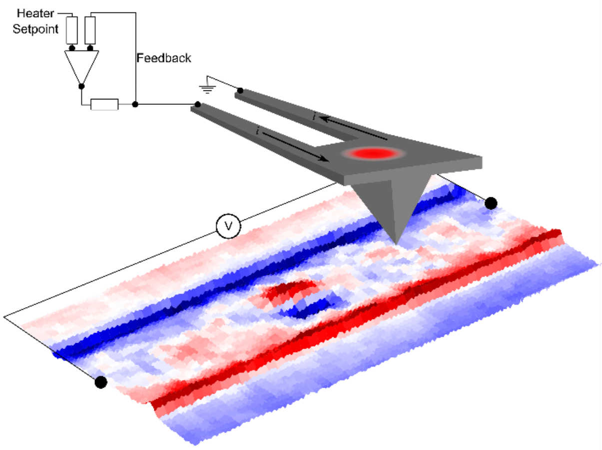

Fig 1: Illustration of the scanning thermoelectric microscopy set-up, where a heated tip is scanned over the sample, and the induced thermovoltage recorded. The data shows the characteristic signal from the edges of the wire as well as the skyrmion in the centre.

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GaAs quantum dots for single-electron current sources

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Generating accurate currents can be achieved in an elegant and direct way by applying a periodic signal to a tunable barrier quantum dot. Such devices are called single-electron pumps (SEPs) due to their capability of emitting a well defined number of n electrons per cycle of an external drive. With driving frequency f and elementary charge e this leads to a controlled and clocked current of $I = nef$, thereby providing a suitable basis for a quantum current standard. While individual SEPs can already achieve errors in the sub-ppm range for currents of the order $I \approx 100$ pA [1], implementing larger systems consisting of multiple well-performing SEPs remains a challenging task. We here present DC transport as well as pumping characteristics of multiple SEP devices toward scaling to higher currents.

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Assessing the effects of space radiation on quantum diamond sensor performance

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Quantum sensors based on nitrogen-vacancy centers in diamond are promising for space applications due to their potential for high-precision measurements. While the technology has been demonstrated in the relatively shielded environment of the International Space Station, its long-term performance in harsher radiation environments beyond low Earth orbit remains largely unquantified. It is therefore important to understand how space radiation modifies the diamond lattice and nitrogen-vacancy center environment, and how these changes translate into sensor performance. This work presents a modelling workflow that links space radiation across multiple mission environments to the expected degradation in diamond sensor performance. Using radiation-environment models for each scenario, particle interactions in diamond are simulated to extract depth-dependent vacancy production, defect creation, and cumulative damage profiles as a function of mission duration. The impact on sensing is then assessed using simulations based on double electron-electron resonance to estimate performance degradation. The workflow provides a quantitative link between radiation-induced lattice damage and expected sensor performance, enabling comparison across mission durations and radiation environments. It supports selection of diamond with certain parameters, mission design, and mitigation strategies, while defining clear targets for experimental validation of radiation effects on quantum sensing performance. This study is a step toward developing sensitive and stable diamond quantum sensors suitable for longer-duration missions aimed at interplanetary and planetary exploration.

Laser-Based Creation of Room-Temperature Quantum Emitters in Hexagonal Boron Nitride

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Quantum emitters in hexagonal boron nitride (hBN) have attracted significant interest for applications in quantum communication, sensing, and integrated nanophotonic circuits due to their ability to operate at room temperature. A key challenge, however, lies in the reliable fabrication and rapid identification of optically active defects with high single-photon purity. In this work, we present a laser-based method for generating quantum emitters in hBN using single-shot laser pulses, combined with an efficient confocal screening approach. Raman-based imaging of the host lattice is employed to locate laser-affected regions prior to emission measurements, enabling fast correlation between structural modification and optical response. Our results show that single-photon emission arises only within a narrow processing regime where lattice damage is limited. Spatially resolved Raman analysis reveals localized strain surrounding optically active sites, indicating a strong link between strain and emitter activation. The laser-induced defects fall into two distinct groups: narrowband emitters in the 650–750 nm range with weak phonon sidebands, and emitters between 600 and 650 nm that show stronger vibronic coupling; both groups exhibit linear polarization and high single-photon purity at room temperature. This study demonstrates a scalable laser-based protocol for creating quantum emitters in hBN and provides practical insight for their integration into future quantum photonic platforms.

Modelling of a Shallow Elliptic Quantum Dot in a Transverse Magnetic Field

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To improve the accuracy of a single-electron pump, it is important to understand its operation in the shallow quantum dot regime. A key element in the analysis of electron transfer in the electron pumping process is the transition from confined electrons to ballistic motion in the quantum dot. We present a theoretical model that provides a microscopic description of systems with one and two electrons in a shallow elliptic quantum dot. Electron loading into discrete quantum dot states has been studied experimentally by Wenz and coworkers (2019) [1], who measured energies and tunneling rates at zero magnetic field. However, it remains difficult to determine the microscopic parameters of shallow quantum dots experimentally. We calculate eigenstates of one electron and of two interacting electrons in both a symmetric and a strongly anisotropic quantum dot by diagonalizing the system Hamiltonian over a range of shallow quantum dot parameters and magnetic field strengths. We study the sensitivity of the eigenstates to these parameters in order to predict the physical conditions under which experiments should be performed to optimally characterize the shallow quantum dot, for example by anisotropy parameter of the quantum dot. Knowledge of the anisotropy parameter would allow us to assess the applicability of simplified theoretical models such as the 1D cubic potential model by Akmentinsh and coworkers (2024) [2, 3] in a description of physical realizations of single-electron pumps.

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Landau level single-electron pumping

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Abstract

We investigate single-electron pumping in a high-precision finger-gate split-gate device subjected to a strong perpendicular magnetic field. In the quantum Hall regime, electron transfer occurs from discrete Landau levels in the leads, and the resulting pumped current exhibits pronounced magnetic-field-dependent fluctuations in the lengths of the quantised pumping plateaus. These oscillations closely resemble Shubnikov–de Haas behaviour, suggesting a direct connection between pump dynamics and the electronic structure of the leads.

To explain this phenomenon, we develop a physical model describing the capture and emission dynamics of the pump. The model shows that the pumping process is governed by the density of states of the two-dimensional electron gas within a narrow energy window. Comparison with experimental data enables extraction of key physical parameters, including the electron capture energy, Landau level broadening, and the quantum lifetime of electrons in the leads.

Our results provide a quantitative framework linking single-electron pump operation to Landau quantisation and demonstrate how magnetic-field-dependent lead properties influence pumping accuracy. This work advances the understanding of dynamic quantum dot devices operating in the quantum Hall regime and has implications for precision charge pumping and quantum metrology.[1]

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Pair and chiral superfluidity in subwavelength triangular ladders

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Spontaneously symmetry-broken (SSB) phases are ubiquitous in nature, ranging from crystalline order to superfluidity and superconductivity, and their controlled realization remains a central goal in the field of quantum simulation. Ultracold atomic systems provide an exceptionally clean and tunable platform for exploring such collective phenomena. A paradigmatic example of SSB is superconductivity, where fermions form Cooper pairs that condense into a phase-coherent macroscopic state. Understanding how pairing and phase coherence arise in lattice systems with engineered interactions is therefore of fundamental interest.

In this work we demonstrate that coupling ultracold atoms in a particular Lambda scheme realizes a frustrated, non-standard Bose–Hubbard model with strong pair hopping and density-induced tunneling. Starting from the dark-state Wannier basis, we derive the extended Bose-Hubbard Hamiltonian. We then use density matrix renormalization group (DMRG) calculations to map out the many-body phase diagram. We find that interaction-driven pair tunneling stabilizes a robust pair superfluid, characterized by power-law decay of pair correlations and gapped single-particle excitations. Additionally, a chiral superfluid arises from frustration induced by competing nearest neighbour (NN) and next-nearest neighbour (NNN) tunnelings. Finally, by mapping the strong-pairing regime onto an effective XXZ spin model, we provide analytic insight into the origin of these phases and their phase boundaries. Our theoretical results establish subwavelength state-dependent lattices as a versatile route to realizing pairing, frustration, and unconventional superfluidity with ultracold atoms.

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Thin amorphous molybdenum silicide superconducting shells around individual nanowires deposited via magnetron co-sputtering

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Employing amorphous superconductors, such as Type-II molybdenum silicide (MoSi), instead of crystalline materials significantly simplifies the material deposition and scalable nanoscale prototyping, beneficial for quantum electronic and photonic device fabrication. In this work, deposition of amorphous superconductive MoSi thin films on flat and nanowire (NW) substrates was demonstrated via pulsed direct-current magnetron co-sputtering from molybdenum and silicon targets in an argon atmosphere. MoSi films were deposited on oxidized silicon wafers and Ga_2O_3 NWs with 6 nm Al_2O_3 insulating shell, grown around the NWs using atomic layer deposition, and studied using scanning and transmission electron microscopy, X-ray diffraction, and X-ray photoelectron spectroscopy. Four-point Cr/Au electrical contacts were defined on the thin films and on individual Ga_2O_3-Al_2O_3-MoSi core-shell NWs using lithography for low-temperature electrical measurements. By controlling the sputtering power of the targets and thus adjusting the molybdenum-to-silicon ratio in the MoSi films, their properties were optimized to achieve critical temperature T_c of 7.25 K. Such superconducting shell NWs could provide new avenues for fundamental studies and interfacing with other materials for quantum device applications.

To promote further collaboration, materials growth and nanofabrication capabilities at Institute of Solid State Physics, University of Latvia will be briefly presented.

SRIM calculations of ion implantation in diamond for membrane fabrication

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Scalable optical quantum technologies require photonic integrated circuits[1] that can efficiently generate, manipulate, and route quantum states of light. Such circuits should support e.g. spin-photon interfaces, and coherent links between different quantum devices. In particular, diamond is a promising platform that can combine spin defects with monolithic nanophotonic structures. Moreover, integrating diamond with nonlinear optics materials can marry diamond qubits with on-chip fast optical modulation and frequency conversion to telecom wavelengths.[2]

The development of such hybrid platforms can be facilitated by the fabrication of thin diamond membranes.[3] These membranes can be bonded to nonlinear photonic substrates and simplify multistep fabrication processes without compromising the quality of nanophotonic devices. Diamond membranes may be produced from bulk diamond substrates using a smart-cut approach, in which a subsurface graphitized layer is formed by ion implantation followed by thermal annealing.[4] After microwave-assisted plasma-enhanced chemical vapor deposition diamond overgrowth, this damaged layer can be removed through electrochemical etching, enabling membrane release.

In this work, the ion implantation step of the diamond membrane fabrication process is modeled using The Stopping and Range of Ions in Matter software[5] for ion species He^+ and C^+. Stemming from these calculations, implantation energy and fluence parameter sets are determined as a function of the targeted depth of the subsurface damaged layer. Based on these results, diamond membranes will be fabricated for the realization of a diamond-on-insulator photonic chip for spin-photon interfaces and nanoscale NMR sensing.

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From Quantum Sensing to teaching Quantum with NV Centers

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Nitrogen-Vacancy (NV) centers in diamond have emerged as a leading quantum technology platform, owing to their long coherence times, optically addressable spin states, and high sensitivity to external perturbations.
In this poster, we highlight two application areas of NV centers.
First, a single NV center in a diamond scanning tip functions as a nanoscale quantum sensor enabling measurements of magnetic field, current density distribution, and near-field optical or sub-surface signals. Our commercial scanning NV system, Quantum Scanning Microscope combines single NV center technology with atomic force microscopy and confocal optical readout to study magnetic phenomena with high spatial resolution in a fast and user-friendly way. This system enables studies of materials such as antiferromagnets, and multiferroics, as well as magnetic textures like spin waves, and skyrmions. Recently, we have extended the capabilities of our system to facilitate measurements at cryogenic temperatures, allowing the study of various superconducting phases and two-dimensional magnetic materials.
Second, because NV centers in diamond operate under ambient conditions, they provide an ideal platform to demonstrate a wide variety of quantum phenomena. We have developed an educational kit based on NV centers, Quantum Edukit to teach quantum mechanics in a hands-on and interactive manner. The kit enables exploration of principles such as level quantization, quantum superposition, light-matter interaction and quantum optical effects in real time. Sample experiments include observation of the Zeeman effect, Rabi oscillations, Ramsey interferometry, and spin echo. On an experimental level, students gain hands-on experience in building optical setups, optimizing the performance of quantum systems, and acquiring practical skills used in quantum research labs.
These applications illustrate the versatility of NV centers, enabling both nanoscale sensing and interactive education in quantum mechanics.

Temperature sensing using double quantum resonance of Nitrogen-Vacancy centers in diamond

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Quantum sensors based on color centers in diamonds have potential applications in different fields from the biomedical, electronic and battery technology sectors to space applications [1]. They can sense magnetic fields B, temperature T, electric fields E, strain fields and pressure [2]. When used as thermometers, they provide milli-kelvin and sub-milli-kelvin sensitivity. Here we report on a sensing protocol in which one can switch between temperature and magnetic field sensing modes in a nitrogen vacancy based sensor. This is under an optically detected magnetic resonance detection scheme with frequency modulated microwave signal and in double resonance excitation mode [3]. This protocol allows the suppression of magnetic field interference up to two orders of magnitude in temperature sensing mode. This can be done by tuning the relative phase of the frequency modulated microwave signals. Moreover, phase tuning allows suppression of temperature effects in magnetic-field sensing by up to two orders of magnitude and can also correct asymmetries in the double-resonance mode. Using the mentioned protocol, we monitored temperature variation in diamond due to MW excitation pulses with mK resolution.

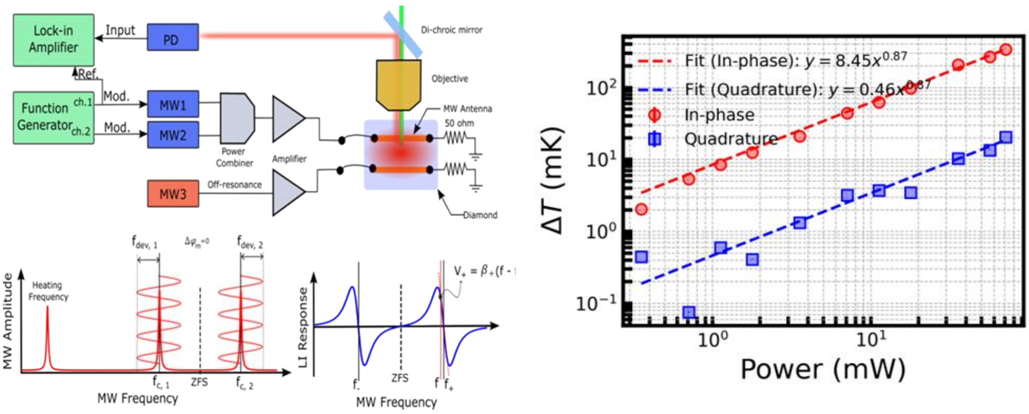

Figure 1: (Left) Schematic overview of the temperature sensing setup in a frequency modulated double resonance protocol. Here microwave 1 and 2 are used to drive the spin transitions while microwave 3 is used to is used to heat up the sample. (Right) Measured temperature changes for different microwave powers with the relative phase between the modulation signals being 0.

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Enhancing Quantitative Magnetic Force Microscopy through NV Calibration

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Magnetic force microscopy (MFM) is a versatile tool for imaging magnetic stray fields at scales down to 10 nm and 100 µT. Traditionally, MFM measures qualitative data, such as phase or frequency shifts. To obtain quantitative data, specifically magnetic stray fields expressed in A/m, knowledge of the tip's stray field distribution is essential. Although MFM tips can be modeled using effective dipole and monopole moments, these simple models apply only to specific tip shapes and are not universally valid.

A proven approach for silicon-based tips with magnetic coatings is the transfer-function method [1]. By measuring a known reference sample [2], the tip transfer function can be derived from the measured data. This calibrated tip allows qualitative measurement data from a sample under test to be converted into quantitative stray field data in A/m.

However, this approach is limited by the Fourier components that the reference sample can provide, which constrains the maximum obtainable resolution during MFM data calibration. In a recent study [3], we investigated this limitation and compared a transfer-function-based tip calibration to a calibration using a tip characterized in a nitrogen vacancy (NV) microscope. We demonstrate that the NV-calibrated tip captures higher Fourier components, significantly improving calibration for samples exhibiting small feature sizes. Such quantum-calibrated tips hold the potential to better understand and enhance quantitative MFM (qMFM) measurements in future applications.

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Crosstalk compensation for an M_x magnetometer-based gradiometer

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Geophysical applications, such as the detection of unexploded ordnances or the search for mineral resources, require highly sensitive, magnetic field sensors with a large dynamic range to resolve magnetic anomalies in the presence of the Earth's magnetic field. A gradiometric configuration of two or more optically pumped magnetometers is advantageous for this application since the influence background fields and common mode noise is suppressed.
However, some magnetometer types (e.g. M_x magnetometer) use radio frequency fields to obtain magnetic field information, which leads to unwanted crosstalk in the magnetometer signals.
In this study, we present a technique to suppress the impact of crosstalk between two M_x magnetometers operating as a semi-intrinsic gradiometer. To achieve this, we employed a dual in- and output channel field programmable gate array (FPGA) board. The FPGA output channels serve as radio frequency generators for each of the two M_x magnetometer coils, which are used to drive the magnetic resonance in the vapor of polarized Cs atoms, while the FPGA input channels are used to record the cell-transmitted light power. A digital lock-in demodulates at the respective channel's radio frequency and a phase-locked-loop acts to lock the corresponding generator output to the magnetic resonance frequency. We show that mixing both channel output signals can be used to reduce impact of crosstalk by more than 95% due to destructive interference of the radio frequencies fields at Cs vapor cells.

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In-situ Detection of Free Radicals using Nitrogen Vacancy (NV) Center-based T_1 Relaxometry

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NV centers combine a remarkable sensitivity to magnetic fluctuations with the ability to operate at room temperature and in liquid environments [1]. They are therefore particularly attractive for chemical and catalytic research, where paramagnetic intermediates such as short-lived radicals or transition-metal complexes play a central role [2]. The direct observation of such intermediates has so far been an experimental challenge, as they typically occur only transiently and at extremely low concentrations. NV center-based T_1 relaxometry enables microwave-free, passive detection of these magnetic fluctuations in the frequency range from megahertz to gigahertz, depending on the applied magnetic field [1, 3]. This allows chemically relevant processes to be investigated in-situ and under ambient conditions, representing a decisive advantage over classical spectroscopic techniques.

In parallel, light-driven redox processes are gaining increasing importance in energy research and catalysis [4]. They are considered a promising approach to enabling sustainable chemical transformations, for example in the production of green hydrogen [5, 6]. A deep understanding of the underlying mechanisms, particularly the formation of reactive intermediates, is essential for the development of stable and efficient systems.

In this study, we successfully demonstrate the feasibility of an in-situ detection using the radical 2,2,6,6-Tetramethylpiperidinyloxyl (TEMPO) and investigate the extent to which these findings can be transferred to cadmium selenide/cadmium sulfide nano-rods (CdSe/CdS NR) with methylviologen as model system for photocatalysis [7].

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Microwave-Free Detection and Imaging of magnetic nanostructures using fluorescent nanodiamond

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Zero-field cross-relaxation (ZFCR) features of nitrogen-vacancy (NV) centers in diamond enable microwave-free magnetic detection and imaging, which is particularly advantageous for bio-related applications [1]. Further, fluorescent nanodiamonds (FNDs) hosting NV centers are non-toxic and biocompatible, making them well-suited for such studies. In this work, using the ZFCR feature of NVs and a home-built optical setup, we observe a characteristic drop in photoluminescence near zero external magnetic field for FNDs. When magnetic nanostructures, such as iron oxide nanoparticles and magnetic pigments in music recording tapes, are placed in close proximity to the FND surface, pronounced variations in cross-relaxation magnetic shifts, contrast, and linewidths are observed compared to FNDs alone. These variations enable the detection and spatially resolved magnetic field mapping of magnetic nanostuctures without microwave excitation or external bias fields, unlike conventional ODMR techniques [2]. Providing a promising platform for quantum sensing and imaging in complex and biologically relevant environments where conventional microwave-driven techniques are disruptive.

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Research on optical whispering gallery mode micro-resonators

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Optical whispering gallery mode (WGM) microresonators made from transparent optical materials operate by the total internal reflection effect of light in a broad wavelength range without the necessity to have any mirror coatings [1, 2]. Previously, we have studied silica microsphere WGM resonator applications for a glucose biosensor [3]. Besides silica, we have made WGMR humidity sensor from glycerol droplets [4] and a laser wave-length sensor from numerous plexiglass (PMMA) microspheres attached to a tapered fiber [5]. Presently, we study integrated polymer optical microring resonators on a glass substrate from SU-8 photoresist made by optical lithography for gas sensing applications [6]. We try to levitate transparent oil microdroplets in optical tweezers, an electrodynamic trap and using diamagnetic levitation.

Second direction of our research is optical frequency comb generation in silica microspheres by Kerr-nonlinearity to create multi-wavelength source that can be used as a laser source in fiber optical fiber telecommunications [7]. We also study microresonators on the chip made from tantala Ta2O5 material that is promising for frequency comb generation as it possesses high Kerr nonlinearity.

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Perhydropolysilazane as a Scalable Gate Dielectric for 2D WTe_2 Based Electronics

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In 2D material based electronics, charge transport can be controlled by an electric field applied through a dielectric-separated gate, making the dielectric's leakage, interface quality, and breakdown strength critical for stable and scalable device operation.[1] For two-dimensional transition metal dichalcogenides (2D TMDCs), dielectric integration is particularly challenging due to the atomically thin nature of the active material and the absence of dangling bonds at the surface, which can lead to charge trapping and reduced electrostatic coupling.[2] These challenges are especially relevant for WTe_2, a layered TMDC exhibiting extremely large, non-saturating magnetoresistance and strong sensitivity of transport properties to carrier balance, making controlled electrostatic gating an important tool for tuning and understanding its electronic behaviour.[3]

Perhydropolysilazane (PHPS) is an inorganic polymer that can be processed from solution and converted into down to few-nanometre thin silica (SiO_2) layer without need for elevated temperatures. Its compatibility with spin-coating and standard lithographic processes makes it attractive for scalable device fabrication, while the resulting silica layer provides effective electrical insulation and protection of 2D TMDC against oxygen and moisture.[4]

Here, we investigate PHPS as a top-gate dielectric material for 2D WTe_2 based devices. We find that PHPS addresses several limitations of conventional top-gate dielectrics, such as high-temperature processing, reactive deposition environments, and poor environmental stability. By enabling room temperature formation of uniform, conformal silica layers with strong adhesion and effective environmental protection, PHPS provides a scalable and reliable dielectric solution for gated electronic devices based on 2D TMDCs. Transport measurements were performed on WTe_2/PHPS top-gate Hall bar devices in a Quantum Design Dynacool system using Hall bar geometry. Gate performance was evaluated by monitoring the resistance modulation and gate leakage current under applied top-gate bias.

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Determination of relative transition probabilities of atomic niobium derived from Fourier transform spectra

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Niobium (Nb), with atomic number 41, is the third member of the 4d-transition group elements and plays an important role in the investigation of the nucleosynthesis of heavy elements in the stars [1] as well as for testing new developments in fundamental physics [2]. It has only one stable isotope ^{93}Nb with nuclear spin I = 9/2 and its atomic spectrum is characterized by a broad hyperfine structure, see Fig. 1, caused by the large nuclear magnetic dipole moment. In present work we report on experimental studies of relative transition probabilities of atomic Nb; such information is necessary to evaluate the element abundance in the stellar atmosphere. The line intensity distributions for a number of line series originating from a common upper level, or branches, were obtained from Nb emission spectra produced in a hollow cathode discharge lamp in an argon atmosphere at a pressure of about 1.7 mbar in visible and near-IR spectral region, recorded by high-resolution Bruker IFS 125 HR Fourier transform spectrometer in the Laser Centre of the University of Latvia, see [1]. Experimental relative intensity distributions have been obtained from measurements of the areas below the line profiles. The respective relative transition probabilities for the branch from the odd parity upper level 24015.11 cm^{-1} are shown in Fig. 2.

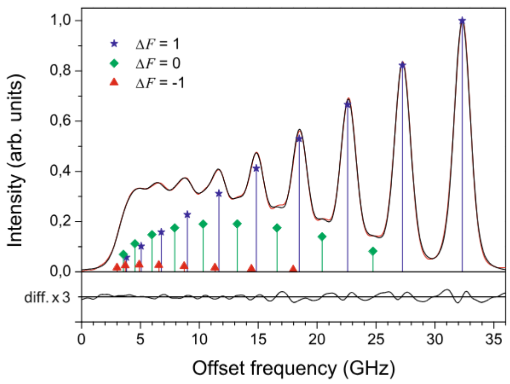

Fig. 1. Example of Nb spectral line from the upper level with energy 24 203.05 cm^{-1} (J = 11/2) to the lower level with energy 2805.36 cm^{-1} (J = 9/2) at λ_{air} = 467.2097 nm together with the best fitted curve.

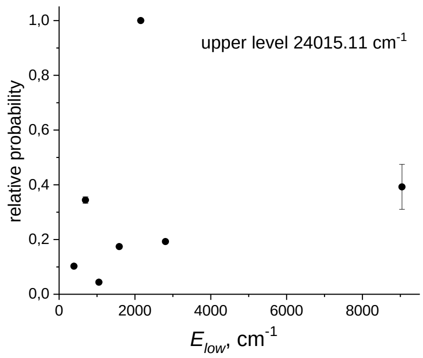

Fig.2. Normalized relative transition probabilities for the branch starting from the common upper level with energy 24015.11 cm^{-1} as dependent on energies of the lower levels.

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Field-gradient spectroscopy of Rydberg positronium in a strong magnetic field

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We present a field-gradient–based approach for quantum-state–sensitive detection of Rydberg positronium in a strong magnetic-field environment. Positronium is a bound state of an electron and a positron and, as a purely leptonic atomic system, provides a clean platform for high-precision tests of quantum electrodynamics.

Positronium atoms are produced from a nanoporous silica target and excited to Rydberg states using two-photon resonant excitation. The excited atoms propagate in a homogeneous magnetic field and are subsequently field-ionised in a spatially non-uniform electric field generated by a high-voltage electrode in a Penning trap configuration.

The combination of controlled electric-field gradients and magnetic guiding spatially separates the ionisation process, such that the detected ionisation position depends on the internal quantum state and transverse velocity of the Rydberg positronium. The resulting positrons are transported along the magnetic-field lines to a position-sensitive microchannel plate detector, where the spatial ionisation pattern is recorded.

This method provides a flexible framework for probing Rydberg atoms in environments with strong magnetic fields and offers a route toward phase-space–resolved diagnostics based on controlled field ionisation. The approach is relevant for experiments employing Rydberg atoms in precision measurement and quantum-sensing applications.

A compact NV diamond magnetometer for contactless current monitoring and low-frequency magnetic communication

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We demonstrate a compact and portable tabletop magnetometer based on negatively charged nitrogen–vacancy (NV) centers in diamond capable of detecting DC to very-low frequency magnetic fields under ambient conditions. The sensor employs a dual optically detected magnetic resonance (ODMR) detection scheme [1], simultaneously driving the $|m_S = 0\rangle \rightarrow |m_S = \pm 1\rangle$ ground-state transitions.

The magnetometer achieves an experimental noise floor of ≈ 2.3 $nT/Hz^{1/2}$ and a calculated shot-noise-limited magnetic sensitivity of ≈ 585 $pT/Hz^{1/2}$ under continuous wave excitation at 0.5 W of green laser power [2].

We validated the sensor in two representative use cases: contact-free electrical current sensing and low-frequency magnetic field communication. We used a commercial magnetic field sensor - Twinleaf VMR and performed analytical and numerical (COMSOL) calculations to confirm our results.

We acknowledge the support from: Recovery and Resilience Facility project "Internal and External Consolidation of the University of Latvia" (No.5.2.1.1.i.0/2/24/I/CFLA/007), grant project “Single Photon Sources for Quantum Technologies Using Nitrogen-Vacancy Centres in Diamond”, No. LU-BA-PA-2024/1-0071, ESS2024/465-PA-05, the Latvian Council of Science, project No. lzp-2021/1-0379: “A novel solution for high magnetic field and high electric current stabilization using color centers in diamond” and from LLC “MikroTik” and the Foundation of the University of Latvia, project No. 2320: "A system for precise detection of double quantum magnetic resonance".

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Towards in-situ Twistronics using the Quantum Twisting Microscope

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Twistronics, the field of study where two or more layers of van der Waals crystals are rotated with respect to another to engineer new emergent phenomena, is a rapidly evolving field of research with exciting new discoveries. This is fueled by the fact that the new twist-angle degree of freedom gives researchers unprecedented control over the band structure of crystals. Several exciting discoveries such as the flat band [1], correlated insulator [2], and unconventional superconductivity [3] in two sheets of graphene twisted to its magic angle of 1.1° underline twist-angle as a new and powerful tuning parameter. However, an outstanding concern in the community is the difficulty in fabricating the magic-angle devices [4], lack of reproducibility [5] and uncontrollable inhomogeneity in the samples [6,7], which are inhibiting the rate of progress. To address these issues, several in-situ twisting methodologies have been invented [8,9,10], which alleviate the abovementioned problems. In particular, the quantum twisting microscope (QTM) has gained intense attention, as it not only provides a way to twist two layers to the magic-angle with millidegree precision, but also provides direct measurement of the band structure with an inclusion of an interfacial tunnel barrier [10,11]. The QTM uses an atomic force microscopy architecture fashioned with a rotating sample platform, where the cantilever and the sample are coated with 2D materials. In my poster contribution, I will present the progress of my group, which is currently developing the hardware and samples for QTM.

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Photonic integrated top-hat beam profiler for multi-ion clock application

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Multi-ion optical clocks offer improved precision by reducing the averaging time. To minimise intensity-dependent AC Stark shifts on individual ions, highly homogeneous illumination is essential. The optimal beam shape for this purpose is a top-hat intensity profile. This has previously been achieved using holographic waveplates in free space, but this approach limits spatial uniformity [1]. We demonstrate that an extreme mode converter, implemented on an Al_2O_3 photonic material platform, can generate this top-hat profile for the 370 nm Doppler cooling transition of Yb^+ ions, thereby increasing the modal area of the waveguide mode by a factor of $\sim 10^4$. This integrated photonic approach provides a path towards improved beam homogeneity and scalable multi-ion clocks, overcoming the limitations imposed by freespace optics.

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Near transform-limited single photons from rapid-thermal annealed quantum dots

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Single-photon emitters are essential components for quantum communication systems, enabling applications such as secure quantum key distribution and the long-term vision of a quantum internet[1,2]. Among various candidates, self-assembled InAs/GaAs quantum dots (QDs) remain highly promising due to their ability to emit coherent and indistinguishable photons, as well as their compatibility with photonic integration[3]. In this work, we investigate the impact of post-growth rapid thermal annealing (RTA) on the quantum optical properties of single self-assembled QDs embedded in a p-i-n diode structure. The annealing process induces a controlled blueshift of the emission wavelength by promoting Ga in-diffusion and intermixing. Using resonance fluorescence measurements at cryogenic temperatures (4.2 K), we investigate the single-photon statistics, the emission linewidths, and coherence time T_2 of the emitted photons. Our results show that, despite the high annealing temperature of $760\,^{\circ}\mathrm{C}$, the process does not degrade the optical quality of the quantum dots strongly. Instead, we observe single-photon emission with near transform-limited linewidths, where the dephasing time T_2 is only a factor 1.5 above the Fourier-limit $T_2 = 2T_1$. These findings demonstrate that rapid thermal annealing (RTA) serves as an effective tuning method that preserves the key single-photon emission properties and may help reduce undesirable effects such as non-radiative Auger recombination in quantum photonic applications.

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Optimal Observables and NMR sensors

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February 5, 2026

We present a theoretical and numerical study on the optimization of measurement observables for quantum sensing, with particular emphasis on Nuclear Magnetic Resonance (NMR) sensors. Within the framework of Symmetric Logarithmic Derivative (SLD) theory, we derive optimal observables that maximize parameter sensitivity and enable saturation of the quantum Cramér–Rao bound.

We validate the proposed approach through numerical simulations of the Quantum Fisher Information using the method of moments and demonstrate its application to an NMR-based quantum sensor. The results show a clear enhancement in precision compared to non-optimized measurement strategies, establishing SLD-based observable optimization as a practical and powerful tool for improving sensitivity in NMR quantum metrology.

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Exploring nonlinear-Zeeman-effect-free magneto-optical signals from high-order coherences in atomic Rb

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While atomic magnetometers excel at measuring zero to ultra-low fields, the nonlinear Zeeman (NLZ) effect compromises their accuracy in the microtesla range (e.g., Earth-scale fields). Although various techniques have been developed to correct NLZ-related errors, this study introduces a signal that is naturally immune to these effects. Our approach utilizes the $m = \pm 2$ sublevels of the ^{87}Rb $F_g = 2$ ground state, as their energy levels scale linearly with magnetic field strength. Building on the methodology established in [1], we demonstrate how the creation of $\Delta m = 2$ coherences facilitates the development of $\Delta m = 4$ coherences to improve sensor performance.

We intend to increase the accuracy of ^{87}Rb atomic magnetometers by completely eliminating the NLZ heading error via the creation of hexadecapole moments ($\Delta m = 4$ coherences) with a precise sequence of modulation pulses and to improve sensitivity by using fluorescence instead of optical rotation.

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Chiral Anomaly-Driven Quantum Transport in Tellurium Weyl Semiconductor Nanoribbons

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Like topological insulators, Weyl materials provide a unique platform for exploring topologically protected quantum transport, combining strong spin-orbit coupling and band inversion with the tunability of conventional semiconductors. A hallmark of Weyl semiconductors is the chiral anomaly, which gives rise to an additional current in parallel electric and magnetic fields, enabling transport with suppressed back-scattering and low-dissipation. Tellurium (Te) is a particularly attractive Weyl semiconductor, as it possesses a finite bandgap while hosting Weyl points in the vicinity of valence/conduction band edges, allowing efficient electrostatic control of topological transport.
Here, we investigate chiral anomaly-driven quantum transport in Te nanoribbons grown by physical vapour deposition and integrated into nanoscale devices. The as-grown nanoribbons are *p*-doped, with typical carrier densities on the order of 10^{18} cm^{-3}. Magnetotransport measurements reveal a clear anisotropy: when an in-plane magnetic field is applied perpendicular to the current ($B \perp I$), a conventional positive magnetoresistance was observed, whereas a pronounced negative magnetoresistance emerges for parallel field and current orientations ($B \parallel I$). The negative magnetoresistance increases as the angle between *B* and *I* is reduced, reaching a maximum for perfect alignment, consistent with transport dominated by the chiral anomaly.
Furthermore, we demonstrate that the chiral anomaly contribution can be efficiently tuned by a gate voltage through control of the Fermi level position. Our results establish Te nanoribbons as a versatile and highly tunable platform for realizing Weyl-based quantum nanodevices and open new opportunities for exploiting chirality-driven transport in quantum sensing, metrology, and topological quantum technologies.

Floquet-theory-based description of single- and double-photon Autler-Townes effect with radiofrequency excitation of Cs atoms

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The rotating wave approximation (RWA), in which the rapidly oscillating terms of the Hamiltonian are neglected, is widely used in atomic physics. The approximation assumes that the Rabi frequency of the oscillating field is small compared to the transition frequency between the energy levels [1, 2]. While this condition holds for laser fields, it may not hold for radio frequency (RF) electric and magnetic fields. An RF magnetic field applied to alkali atoms, which couples Zeeman sublevels, is often used for magnetometry purposes [3, 4]. Theoretical calculations of the observed signals are often done using a model developed in [5], which uses a reduced number of energy levels, thus providing only qualitative dynamics of the signal. Furthermore, the model uses RWA for the RF field Hamiltonian, which is only valid for small field amplitudes. Indeed, it was recently shown in [6] that the model cannot adequately describe higher-order effects related to two-photon magnetic dipole transitions in alkali atoms.

In this work, we derive an alternative description based on Floquet theory. We show that the model can accurately predict the signal features observed in [6], including the impact of RF amplitude leading to magnetic dipole Autler-Townes splitting, which is also observed in the two-photon transition. The model uses the full set of energy levels (F_g={3, 4}, and F_e={3, 4} in case of ^{133}Cs D1 line), and it can be applied to a wide range of excitation geometries.

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NV center gyroscope at zero field

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We present a study exploring the potential of a nitrogen-vacancy (NV) center-based gyroscope operating in a zero-magnetic-field environment. While several gyroscope sequences have been demonstrated using NV centers in finite magnetic fields, their rotational sensitivity could be enhanced if not limited by the stability of bias magnetic fields [1,2]. To address this, we use a dynamic nuclear spin polarization sequence to initialize the intrinsic 14N spin of the NV center, leveraging the optically polarizable electron spin. The nuclear spin precession of its quadrupole-split eigenstates along the NV's intrinsic quantisation axes enables the extraction of directional sensitivity, even in the absence of a guiding magnetic field.

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Mesoscopic Coulomb collisions of on-demand electrons

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Few-electron semiconductor quantum optics devices have various applications in sensing, quantum metrology and quantum computing. Recently, multiple independent experiments [1-3] have been performed with electrons propagating ballistically at energies form tens to a hundred of meV above the Fermi level, opening up a previously unexplored regime dominated by Coulomb interaction. In complementary experiments by Ubbelohde *et al.* [1] and Fletcher *et al.* [2], chiral electrons are counterpropagating ballistically along the edges of a 2D GaAs/AlGaAs heterostructure and collide at a mesoscopic constriction. In work by Wang *et al.* [3] two electrons are transported along depleted quantum rails by means of a surface acoustic wave and reciprocal gating effect due to Coulomb interaction is demonstrated in tunnel coupled region.

We apply the microscopic analytical model for Coulomb collisions of chiral electrons that was developed [1,4] for interpretation of the experiments at PTB [1] to the experimental results of NPL as reported in [2]. We show that the model applies well to both experiments and allows for efficient determination of the key parameters of the beam splitter, namely the maximal interaction strength U and the dispersion constant ω. We find $U/\hbar\omega \gg 1$, consistent with the strongly non-linear regime for both experiments.

We also compare the Bayesian model for reciprocal gating developed for SAW-driven collisions in [3] to the picture of shifted transmission thresholds developed in [4]. We find that both models are equivalent on the mean field level and can be used for qualitative interpretation of interaction signatures both for co-propagating and counter-propagating electrons. However**,** the energy and time dependence of the shifted transmission thresholds as predicted by the analytical microscopic model [1,4], enables quantitative simulations and captures the dependence of the gating strength on the interarrival time which can be continuously varied in the setups of [1] and [2]. We argue that the consistency and complementarity of the results in [1-3] underpin the interpretation of the interaction-dominated collision statistics as a quantum non-linear optics effect.

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Three NV centers with dipole-dipole coupling for quantum applications

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Nitrogen-vacancy (NV) centers in diamonds are known for their spin-dependent photoluminescence and photocurrent, a millisecond coherence time at room temperatures [1, 2]. Aiming to build a proof-of-concept quantum computing register, we are currently demonstrating a setup and a toolset for analysis and control of coupled electron-spin states of NV-centers. For that purpose, we use ^{12}C-enriched CVD diamond with single NVs implanted at high fluency, which possess both coherence time $T_2 \simeq 300\mu s$ and several NV centers occurred in a one fluorescent spot, like NV couples and trios. Then we analyze T_2 value for each NV in a couple/trio. Finally, we demonstrate pair-wise dipole-dipole interaction using DEER measurement and estimate relative distance between NVs in this register (see Fig.). This completes a basis for further analysis of an NV quantum register as tool for application of entanglement-based sensing and logical quantum gates operation.

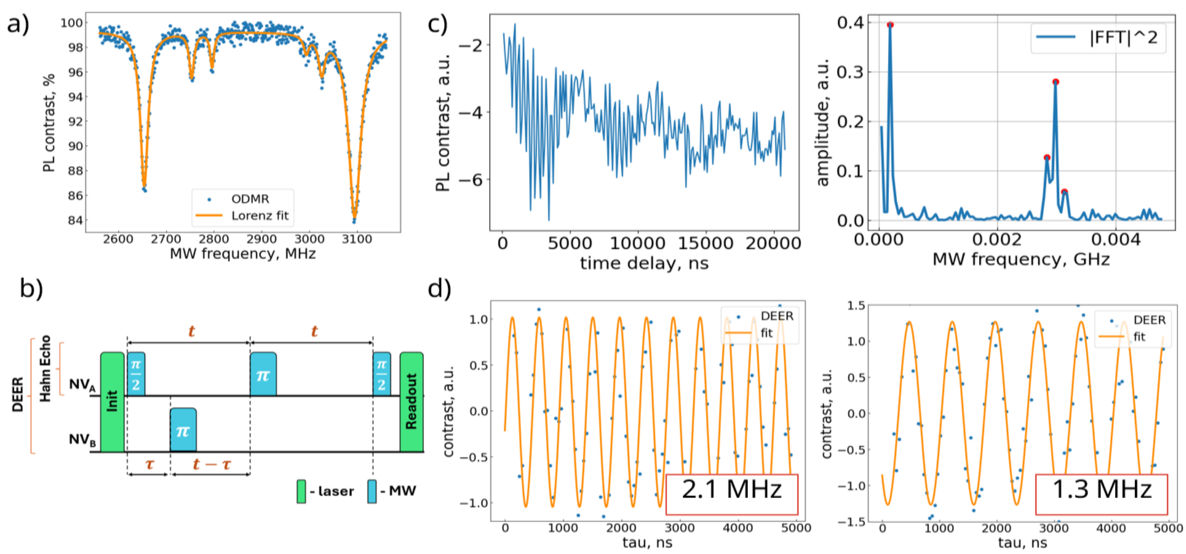

Figure. a - ODMR of three nearby NV centers; **b** - Pulse sequences used for Hahn Echo and DEER measurements; **c** - Hahn Echo signal and its FFT characterized by exponential decay modulated with Larmor (280kHz) and hyperfine (3MHz for 15N) modulations; **d** - DEER signals characterized by dipole-dipole interaction between NV1-NV2 (2.1 MHz) and NV1-NV3 (1.3 MHz).

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UV mirrors with enchanted Optical Phase Shift control using combination of standard and structural coatings

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Nowadays, with growing quantity of information and significant part of it becoming classified demand for new ways to process it is being considered and looked into. Additionally, with the constant military threat and military conflicts around the word classified information encoding is becoming more and more crucial. Due to these reasons various scientific groups are working toward implementing Quantum applications in order to solve these challenges. Quantum computing and Quantum communication receiving significant attention [1,2].The mentioned advanced technologies operate in a Quantum scale due to this reason it operations require precise optical components exhibiting exceptional parameters. The mentioned applications requires laser systems capable of operating at Ultraviolet (UV) and Visible (VIS) wavelengths often with high repetition rates and high powers. Requirements for the system to operate in the UV regime addresses challenges to required optical components since long lifetime, low scattering and precise spectral performance in UV is difficult to achieve.

Classical optical components production methods tend to show limitations in achieving improved values of the lifetime and optical phase shift due to the nature of the used coating and substrate material, and coating technology methods constraints. Optimizing coating deposition speed, adding additional pre-treatments, or implementing other improvement methods could potentially increase optics performance; however, the applications require far superior results. In order to develop and enhance performance, new production approaches have been explored using advanced metamaterials, such as structural coatings deposited via the Glancing Angle Deposition (GLAD) method [3]. Other scientist researches showed that structures have been showing significant improvement for LID and reduced scattering in the UV wavelengths. However we were not able to find any of the works researching GLAD coatings impact to the components Optical Phase shift. Our simulations and theoretical designs have shown that combining IBS and GLAD coating techniques optimizes and enhances the achievable Optical Phase shift values [4].

During this work, we have implemented the UV mirrors production concept combining IBS and GLAD techniques. We simulated and produced dual-wavelength mirrors for the 399 and 369nm wavelengths working at a 45-degree angle of incidence. The design consists of GLAD deposited structural SiO2 and IBS deposited HfO2 and TaO2. Different designs have been evaluated, and extended research has been conducted for mirrors. Firstly, the 35nm, 50nm, 70nm, and 100nm monolayers of Structural Silicium have been deposited with GLAD. Structures were used in order to generate the ellipsometry model. Ellipsometry model is mandatory to evaluate the refractive index of the GLAD structure in the different positions of the structure. As mentioned before the mirror in which design GLAD structure would be implemented will be working at a 45-degree angle of incidence. The result of the measurement and the generated model have confirmed that the refractive index at the top of the structure and at the bottom of the structure is different.

35nm, 50nm, 70nm, and 100nm silica monolayer spectra were measured using the "SpectroPhotometer Photon RT, Esent". The SEM images were taken to check the structure of the deposited film. The theoretical model of the mirrors, possible production strategies, and expected Optical phase shift improvement have been discussed and presented in the work.

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Temperature-Induced Zero-Field Splitting Error Suppression in NV-Centre Vector Magnetometry Beyond the Axial Approximation

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Nitrogen-vacancy (NV) centre–based magnetometry is a promising platform for high-sensitivity vector magnetic field measurements [1]. A key limitation in practical implementations arises from the temperature dependence of the zero-field splitting term D=D(T), with an influence of 75 kHz/K [2], which leads to significant systematic errors in magnetic field reconstruction when temperature measurements of the NV centres are unavailable.

While dual-transition and differential schemes have been explored to mitigate temperature-induced shifts of the zero-field splitting within the axial approximation [3], we study an approach that reduces the dependence of the extracted magnetic field values within the full Hamiltonian to fluctuations in zero-field splitting by exploiting the differences between resonance frequencies rather than their absolute values. This differential analysis suppresses the contribution of the D term by up to four orders of magnitude, enabling more robust, realistic magnetic field estimation without direct temperature knowledge.

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Self-organized hybrid nanostructure arrays for optical sensing

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Ordered arrays of nanostructures, such as metal nanoparticles, are highly attractive for optical sensing because they support a range of light-matter interactions, including localized surface plasmon resonances, guided modes, and Fabry-Pérot resonances, all of which are sensitive to changes in the surrounding medium [1]. Another example is vertically aligned ZnO nanowire arrays, where surface defect photoluminescence (PL) can be exploited for biosensing. By tuning the nanowire length, the surface-related emission can be enhanced while suppressing PL from bulk defects [2].

The fabrication of such systems requires precise control of nanostructure geometry in three dimensions. However, conventional top-down nanofabrication techniques, such as lithography or focused ion beam milling, are limited in scalability, and require advanced instrumentation. This presentation summarizes recent work on self-organized porous anodic alumina (PAA) templates to produce various hybrid nanostructure arrays. Demonstrated systems include short-range ordered metal nanoparticle arrays [3], metal-insulator-metal architectures [1,4], ZnO nanorod arrays [2], and arrays of fluorescent nanodiamonds hosting nitrogen-vacancy (NV) centers [5].

A key technological step is the synthesis of ultra-thin PAA films with thicknesses in the range of ~50–500 nm, enabling efficient optical coupling and compatibility with multiple deposition approaches. Depending on the target nanostructure, fabrication is completed using masked deposition, atomic layer deposition, or capillary-force-assisted assembly of colloidal nanoparticles. The presented results highlight the flexibility of PAA-based self-organization for creating functional hybrid nanostructures with potential for optical sensing applications.

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Entropy in nanodevices — a source of insight and control

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Unlike parameters of immediate practical relevance: conductance, thermocurrent, power, etc; entropy is not frequently considered in nanoelectronics. However, as a thermodynamic parameter which compresses complex unobservable behaviour of a system into a single number, entropy has much to offer in nanoscience, both yielding insight into the inner microscopic dynamics of nanodevices, and acting as a guide to optimising device operation.

In a small system with few degrees of freedom, quantum states of the system — the spin and spatial degeneracy, energy level splitting, etc — can be deduced from the numerical value of entropy. Thus, **direct entropy measurement methods**, which connect the entropy of a nanodevice with experimentally observable parameters, such as conductance, thermoelectric susceptibility, or mean charge, offer new avenues for device characterisation [1]. We demonstrate how the energy level structure of a single-molecule nanodevice can be determined from thermoelectric spectrometry [2].

In the opposite direction, instead of revealing internal dynamics, entropy can be used to concisely abridge them. If the quantum states of a nanodevice are known, finding its operating parameters is a simple problem. However, due to the large parameter space, optimising the performance is not. We show that for the case of a thermal machine, heat engine or refrigerator, based on a single-electron transistor, in which the quantum dot can be more complex than a two-fold spin-degenerate level, all the operating parameters, efficiency, maximum power, efficiency at maximum power, and constancy, depend on only three parameters of the device, the entropy difference between the charge states of the quantum dot, ΔS, being one of them [3]. We show experimental evidence for modifying the performance of a quantum dot heat engine through the application of magnetic field, which changes ΔS [4].

Finally, we suggest a novel entropy measurement method based on RF-reflectometry, which has the advantage of not requiring specialised devices or setup and can be applied to molecules adhered to a surface or impurities in silicon.

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Propagation, dissipation, and breakdown of high-frequency edge state transport in a quantum anomalous Hall insulator

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The quantum anomalous Hall (QAH) effect provides dissipation-free chiral edge transport at zero magnetic field [1]. It offers a promising platform for dissipation-free on-chip guiding of high-frequency signals [2] and for implementing electron quantum optics experiments analogous to those realized in integer and fractional quantum Hall systems [3-4]. Achieving these applications requires reliable microwave control of QAH edge states and a detailed understanding of the breakdown mechanisms that currently restrict operation to very low temperatures (below 100 mK) and small currents (below 100 nA) [5-6]. In this work, we address these challenges by investigating the propagation and breakdown of edge-state transport in QAH insulators under strong electric fields and at microwave frequencies. Using a combination of DC and microwave measurements, we systematically vary excitation voltage, temperature, and magnetic field to identify the onset of dissipation and extract characteristic breakdown scales. We find that dissipation emerges when localized bulk states become electrically activated, leading to Joule heating of disorder-induced charge puddles. Importantly, we observe a crossover from frequency-dependent losses in the well-quantized regime to frequency-independent dissipation once bulk conduction channels are activated, thereby defining the operational window for low-loss microwave control of QAH edge states. Beyond establishing microwave control, our results define the conditions required for single-electron excitation. By coupling two chiral QAH edge channels, we aim to realize controlled charge fractionalization in direct analogy to quantum Hall systems. More generally, the combination of low-loss, microwave-controlled edge states and single-electron excitation establishes QAH insulators as a promising platform for microwave engineering, including on-chip signal routing, nonreciprocal devices, and electron quantum optics experiments in zero magnetic field.

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Quantum Random Number Generation Using Nitrogen-Vacancy Centers in Diamond

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We propose to explore NV centers in diamond as a single photon source to generate quantum random numbers (QRNG) using the emitted excited state photon.

In this project a confocal microscopy-based device is developed for locating and isolating individual NV centers, with the aim of enabling their use in quantum random number generation. The system employs a high-precision piezoelectric positioning stage to scan the diamond sample in the xy plane to identify isolated NV centers, while motion along the z axis allows fine tuning the focus distance. Confocal microscopy is used to restrict the detection volume and isolate a defined cut of the diamond, thereby reducing background fluorescence.

Collected fluorescence is directed towards a 50:50 beam splitter, placing detected photons into a quantum superposition of output paths. Single photon detection is done by using two parallel single photon detectors at each path.

The acquired photon detection events are analyzed using the second-order intensity autocorrelation function $g^{(2)}(\tau)$ to assess photon statistics and to distinguish between bunched, antbunched and single-source fluorescence.

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Fabrication of atomic vapour cells by laser-assisted bonding

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Atomic vapour cells are fundamental components in many modern quantum systems and sensors, including optically pumped magnetometers, atomic clocks, laser frequency references, quantum state storage devices, and electrometers based on Rydberg atoms [1,2].

Traditionally, glass-blown vapour cells have been employed, utilizing specialized organic wall coatings to preserve atomic spin states – a process that, even today, relies heavily on empirical expertise. The development of microfabricated vapour cells based on wafer-scale anodic bonding enabled the mass production of nominally identical cells. Additionally, it facilitated their functionalization using thin-film processes for integrating components such as electrodes, magnetic field coils, electrical heaters, antireflective coatings, and optical mirrors. However, due to the process temperature, standard anodic bonding is incompatible with organic thin films required for spin-state preservation and imposes limitations on cell design.

Here, we present a novel approach to vapour cell fabrication based on laser-assisted bonding of glass. Hermetic sealing is achieved through optical contact bonding of glass parts with minimal surface roughness, performed under vacuum or in an inert buffer gas atmosphere. Subsequent laser-assisted bonding ensures long-term connection stability.

Since the laser-assisted bonding is carried out at room temperature with minimal and localized heating of the sample and without the need for application of additional electrical voltages and fields, the range of compatible thin-film processes for cell functionalization is significantly expanded. Furthermore, this method enables the fabrication of all-glass cells and cell arrays with standardized geometries, offering, for example, full optical access to all six faces of a cubic cell. Furthermore, this method enables the use of glass types that are incompatible with anodic bonding.

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Industrial Silicon Metal-Oxide-Semiconductor Spin Qubits as Quantum Sensors for Single-Molecule Magnet Qudits

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Quantum sensing with solid-state spins combines high magnetic-field sensitivity with nanoscale spatial resolution and on-chip integration. Industrial silicon metal-oxide-semiconductor (SiMOS) single-electron spin qubits are presented as cryogenic quantum magnetometers for nearby magnetic moments. The silicon sensor qubit is driven by electric-dipole spin resonance, and its spin state is converted into a charge signal via spin-selective tunnelling detected with a proximal single-electron transistor. Using a compact resonance-tracking protocol based on frequency-swept microwave excitation at a fixed, stable readout point, qubit frequency shifts induced by an on-chip ensemble of magnetic molecules can be detected and quantified. In particular, single-molecule magnets (SMMs) are studied as attractive candidates for long-lived and chemically reproducible multi-level quantum systems (qudits) [1,2]. Finally, sensing-oriented device redesign strategies, guided by self-consistent Schrodinger-Poisson simulations, are outlined to reduce the sensor-sample separation to well below 10 nm and enable a route towards single-molecule sensitivity.

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Optimization of magnetic-field quantum sensing with NV centers

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Nitrogen-vacancy (NV) centers in diamond have become a key platform for precision sensing of magnetic fields at ambient conditions, offering tunable control and readout of spin states. In this work, we compare the coherence properties of NV centers in both bulk diamond and microdiamond samples, examining their performance in DC and AC magnetic field sensing under various pulse sequences—including Ramsey interferometry and dynamic decoupling. By systematically evaluating optically detected magnetic resonance (ODMR), Rabi oscillations, and T_1 and T_2 relaxation times, we identify how different sample forms and control protocols impact sensing sensitivity and coherence.

Our scanning confocal microscopy measurement platform integrates single-photon counting with microwave pulse shaping, pico-second laser excitation and charge dynamics analysis module, thereby enabling optimization of time-resolved control and readout of NV spin states. We demonstrate optimized bulk and single defect ODMR signals, Rabi oscillations, as well as T_1 and T_2 decay profiles. We further show how tailored pulse sequences, such as dynamical decoupling, can enhance sensitivity to both DC and AC magnetic fields across several experimental scenarios.

These results highlight the adaptability and effectiveness of NV-based sensors, with potential applications ranging from fundamental quantum research to nanoscale magnetic imaging. Future work will focus on developing a compact room-temperature operated quantum sensing and information processing platform.

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Designing Moiré Patterns by Strain

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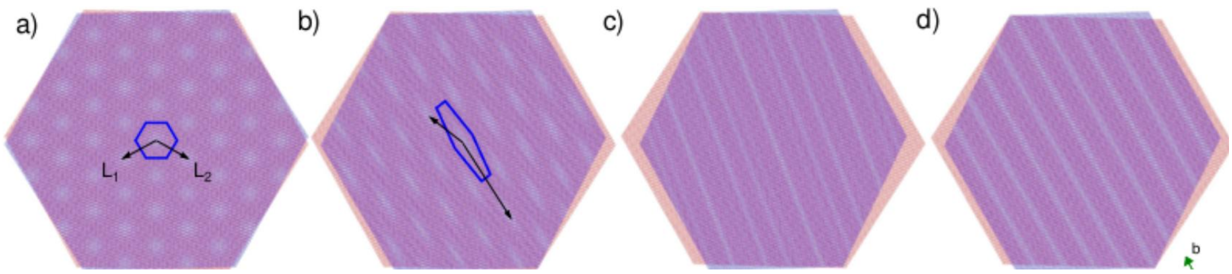
Experiments conducted on two-dimensional twisted materials, involving both twist angle and strain, have consistently shown the presence of a diverse array of moiré patterns with distinct forms and shapes. Especially striking is the appearance of 1D structures under some certain but opaque conditions. In our studies we undertake a systematic investigation of the lattice structure in these systems, taking into account the combined effects of twist and strain. Particularly for moiré systems composed of honeycomb lattices we identified the conditions governing the emergence of such 1D channels and formulate the required criteria for lattice periodicity restoration. By carefully manipulating the strain direction, we have identified a family of engineered moiré systems. These results provide deeper insights into the interplay between twist angle, strain, and lattice structure in two-dimensional layered materials.



Strain induced geometrical effects in a moire superlattice as function of the strain and elastic moduli (Poisson ratio) of graphene. Blue hexagon denotes the moire unit cell in real space. a) A moire sublattice without strain; b) The deformation of the moire supperlattice under moderate strain; c) The emergence of an apperiodic 1d moire superlattice at a critical strain. The system is quasicrystallic; d) The restoration of the exact periodicity by fine-tuning the Poisson ratio to a certain critical value.

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WTe_2 heterostructures for studies of unconventional edge states

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Monolayer and few layer WTe_2 is a promising platform for studying of quantum spin Hall behaviour and harnessing of topological states due to its strong spin-orbit coupling. To experimentally access and characterize these properties, WTe_2 is integrated into hybrid devices, including van der Waals heterostructures and devices with superconducting contacts, which enable probing of topological states.

While initial studies in the literature have demonstrated proximity-induced superconductivity in WTe_2 van der Waals heterostructures and explored Josephson coupling in WTe_2 devices, achieving clean interfaces and well-defined device edges remains experimentally challenging in practice, the control of oxidation and interfacial quality being limiting factors in reported devices. [1-3]

In the present work, approaches are developed to improve material and interface quality for more reliable fabrication and characterization. Devices are fabricated using WTe_2 grown directly on h-BN substrates, as well as mechanically exfoliated WTe_2, enabling systematic comparison of substrate effects and interface quality. Transport measurements are performed on h-BN/WTe_2 and WTe_2/Mo_xSi_{1-x} superconductor hybrid devices.

Initial low temperature transport measurements indicate the presence of superconducting proximity effects. These results provide experimental insight with device fabrication and measurement and form a basis for further fundamental edge state studies in WTe_2 based hybrid structures.

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Monte Carlo simulation of partitioning statistics of a one component Coulomb plasma

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Recent advances in mesoscopic few electron devices have opened new possibilities to probe highly correlated states of matter. Implementation of a mesoscopic collider type experiment [1,2] has enabled measurement of partitioning statistics of few electron droplets necessitating better theoretical understanding of such systems.

The experimental setup consists of loading electrons in two coupled rails, separated by a central barrier, and, with the use of a surface acoustic wave [3], propagating the droplet towards a Y-junction, after which the number of electrons on both sides is measured. We model this system as a classical one-component Coulomb plasma, confined by a quartic-quadratic potential, and employ Monte Carlo methods to investigate its partitioning statistics.

Comparison of experimentally and numerically obtained many-body correlation functions at different temperatures allows us to estimate an effective temperature of 25K in experiments. This value is in line with an estimate obtained from analyzing the central barrier height dependence of thermal hopping rates of a single electron between the two rails. The developed method can be applied to other highly correlated systems, e.g. the 2D electron gas in a strong magnetic field, described by the Laughlin wave function, in order to investigate their partitioning statistics.

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Tellurium-based 1D Nanostructures: Synthesis, Structure and Electrical Transport

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Tellurium-based 1D nanostructures provide a great platform for investigating transport phenomena driven by reduced dimensionality, crystallographic anisotropy, and strong spin-orbit coupling. Tungsten ditelluride (WTe_2) nanoribbons and elemental Te nanowires possess unusual electronic behavior, resulting in potential candidates for future nanoelectronic and quantum technologies.

WTe_2, a layered transition-metal dichalcogenide (TMD), exhibits topologically nontrivial electronic states - including higher-order topological insulator (HOTI) and II-type Weyl Semimetal properties due to its low-symmetry orthorhombic (T_d) crystal structure [1]. Nanoribbons synthesized via chemical vapor deposition (CVD) through tellurization of WO_3 thin films [2] are highly crystalline and grow along the a-axis ($Pmn2_1$ space group), as confirmed by high-resolution transmission electron microscopy (HR-TEM). Electrical and magnetotransport measurements reveal semimetallic, multicarrier behaviour and anisotropic magnetoresistance.

Tellurium nanowires, in contrast, are formed from helical chains aligned along the trigonal c-axis and exhibit intrinsic p-type semiconducting behavior [3-4]. Nanowires synthesized via physical vapor deposition (PVD) were observed to grow along the trigonal c-axis, as confirmed by HR-TEM analysis, potentially indicating a helical structural arrangement. Their structural chirality presents opportunities for investigating chirality-driven transport phenomena.

Overall, these materials demonstrate the functional diversity and tunability of tellurium-based nanostructures, highlighting their potential for use in next-generation electronics.

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Disorder as a Resource: Spin-Glass Quantum Otto Engines for Disorder-Resilient Quantum Devices

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Disorder is typically regarded as a detrimental factor in quantum devices due to decoherence and uncontrolled excitations. Here, we demonstrate that disorder can instead function as a design resource for enhancing and stabilizing quantum thermodynamic performance. We investigate a quantum Otto engine whose working medium is a transverse-field Ising spin glass, combining Bogoliubov-mode analysis with non-equilibrium thermodynamic protocols. Our work builds on recent developments in critical quantum heat engines [1,2] and our recent work on disordered spin-glass working media [4].

We demonstrate that frustration and randomness qualitatively reshape the excitation spectrum and work statistics, resulting in a characteristic double-peaked structure in work output and thermodynamic performance. Near the spin-glass critical point and within Griffiths phases, we observe genuine superlinear scaling of both work output and performance with system size, significantly outperforming ordered Ising-chain devices [4], in contrast to uniform-coupling models [2].

We further demonstrate that disorder stabilizes refrigerator performance across broad temperature ranges and discuss realizability using shortcuts-to-adiabaticity protocols. These results extend earlier studies of quantum thermodynamic enhancement [1] and support a materials-oriented design principle in which controlled disorder acts as a functional element enabling tunability, robustness, and enhanced efficiency in quantum thermal devices, with potential relevance for material-based quantum technologies [3].

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FRET between NV centers in diamond and chlorophyll molecules: a novel resource for multimodal sensing and imaging in plant cells

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We demonstrate Förster resonance energy transfer (FRET) between shallow nitrogen-vacancy (NV) center ensembles in diamond and a naturally occurring fluorophore, namely a mixture of chlorophyll *a* and *b* extracted from *Arabidopsis thaliana*. NV centers located 7 nm and 9 nm below the diamond surface exhibit a strong reduction of their fluorescence lifetime upon deposition of a chlorophyll layer, indicating efficient energy transfer enabled by spectral overlap. Photobleaching of the chlorophyll restores the original NV lifetime. In contrast, NV centers situated deeper in the diamond (40 nm and 72 nm) remain unaffected, confirming the short-range nature of the FRET process. Importantly, the NV centers preserve their optically detected magnetic resonance (ODMR) contrast during energy transfer, highlighting the potential to combine FRET-based distance sensing with magnetic sensing using optically addressable spins.

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Tailored functionalized microfabricated alkali vapour cells

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We present the technology portfolio currently available at Leibniz Institute of Photonic Technology for the fabrication of functionalized microfabricated alkali vapour cells and cell arrays. The vapour cells presented here are the heart-piece of optically pumped magnetometers (OPMs) developed in-house, which are tailored towards specific applications, e.g., for biomedical, geological and geotechnical measurements as well as fundamental physics research questions.
The microfabrication of vapour cells using anodic wafer bonding enables a reproducible large-scale approach and allows their integrated functionalization via thin-film technology. We show how features like transparent electrical heaters [1], cell-lifetime-improving layers [2], anti-reflective coatings as well as optical mirrors [3] and combinations of these features can be implemented. Furthermore, we show integration of microfluidic channels and very thin silicon nitride membranes, possibly interesting for very short sensor stand-off.
A major challenge faced is to maintain compatibility of the additional steps for functionalization with the process parameters required for anodic bonding and the desired wafer-scale handling. In this view, we will also present novel ideas in filling the vapour cells connected to avoidance and/or cleaning their optical windows from unwanted contaminations released during the fabrication process.

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Metrological Evaluation of Gas Sensing in Printed 2D Transition Metal Dichalcogenide Films

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Two-dimensional transition metal dichalcogenides (2DTMDs), including molybdenum disulphide (MoS_2) and tungsten disulphide (WS_2), are graphene like, atomically thin materials whose electronic properties differ markedly from those of their bulk forms. Owing to their high surface to volume ratio and sensitivity to surface adsorbates, these materials show significant promise for gas sensing applications.

In this work, we present a collaborative study between National Physical Laboratory (NPL) and DZP Technologies (a UK company specializing in printed electronics innovation). We focus on the gas sensing performance of printed 2DTMD semiconductor films. The materials were fabricated using a scalable printing process, forming continuous films composed of individual TMD flakes with high surface area and a high density of structural defects, both of which enhance interactions with gaseous species.

Electrical characterisation was conducted using NPL's Electrical Transport Measurements in Variable Environments platform, which enables measurements under controlled conditions: vacuum ($<10^{-4}$ mbar), regulated humidity, exposure to test gases, and elevated temperatures. Automated AC impedance measurement capabilities were employed to investigate changes in key electrical properties, such as resistance and reactance in a large frequency range, as functions of environmental parameters. Not only would this provide considerably more data, it would also give users the opportunity to predict how it might perform under different circumstances. Using this approach, we systematically measured responses to inorganic gases including ammonia, nitrogen dioxide, as well as to humidity. The results provide robust evidence of the sensing capabilities of printed 2DTMDs. This work establishes a foundation for the reliable evaluation of emerging 2D material-based sensors and supports their potential deployment in environmental monitoring and industrial health and safety applications.