Annual Report | 2022

Center for Quantum Spintronics

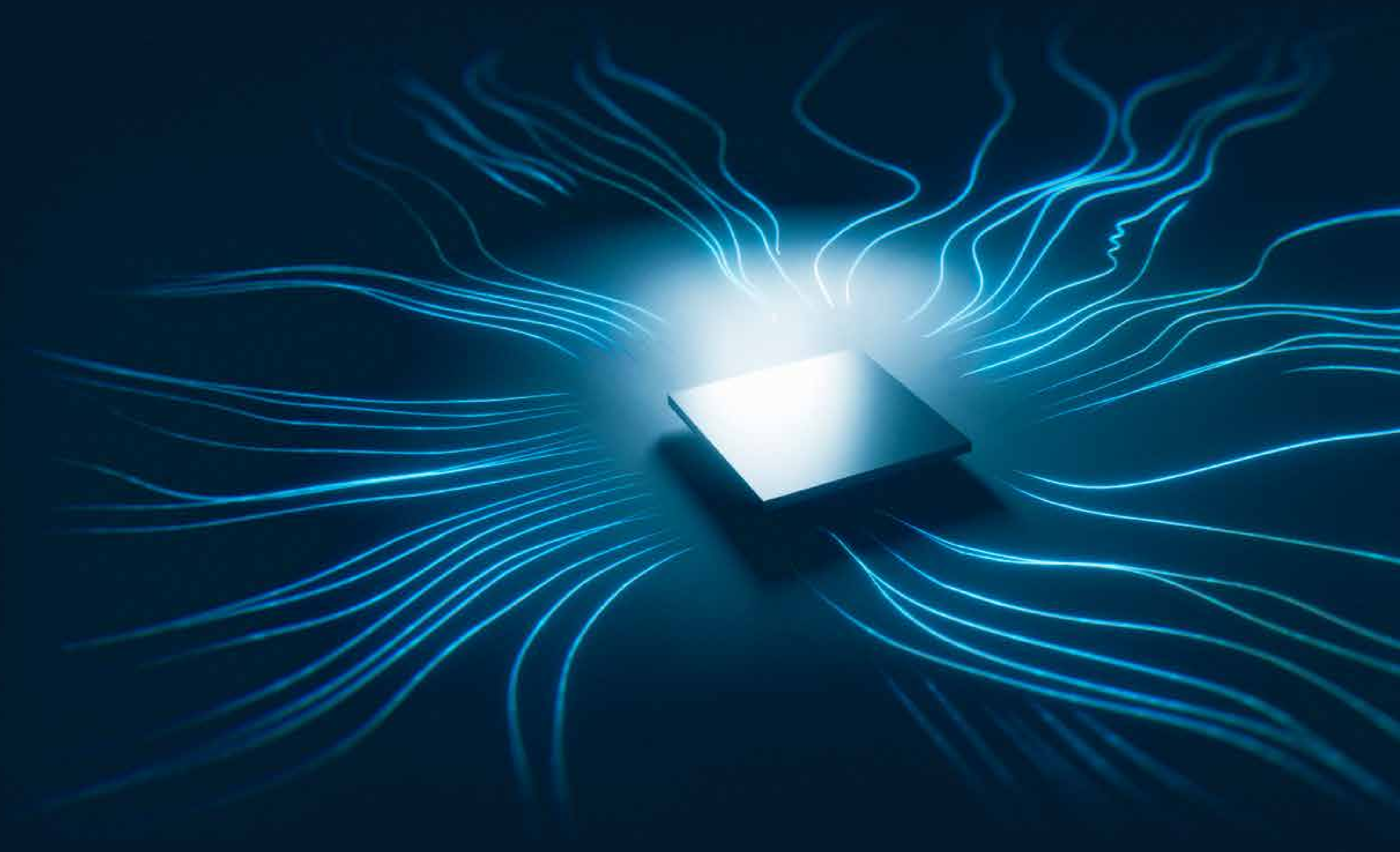
QuSpin

Norwegian Centre of Excellence
The Research Council of Norway

NTNU
Norwegian University of Science and Technology

Our Vision

is to trigger a revolution in low-power information and communication technologies in an energy-efficient society.



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THE ELECTRON SPIN: *The electron spin, the electron's magnetic moment, is a prime example of a quantum entity. Classically, when the earth orbits around the sun, it has an orbital angular momentum. The spin is the electron's intrinsic angular momentum. It is as if something orbits inside the electron. While such an analogue can be useful, it is not what really happens. Instead, the spin is an intrinsic property of the electron. Furthermore, in measurements, there are only two possible outcomes of the spin, clockwise rotation or counter-clockwise rotation. We denote these states as spin-up and spin-down.*

CENTER DIRECTOR ARNE BRATAAS

QuSpin at Midterm

QuSpin is a Center of Excellence funded by the Research Council of Norway and the Norwegian University of Science and Technology. We inaugurated our activity in the fall of 2017. Like all Centers of Excellence, we will receive funding for 6+4=10 years.

Our primary mission is to contribute to the world's scientific endeavors with high-quality research in the field of quantum spintronics. We are proud that by midterm, we had published thirty-five groundbreaking papers in our area's most celebrated non-profit journal, Physical Review Letters. Additionally, more than a hundred and twenty papers have appeared in the renowned non-profit Physical Review journals. We have also published in Science, Nature, Nano Letters, Materials Research Letters, Nature Physics, Nature Materials, Nature Nanotechnology, and Nature Reviews Physics. The number of citations keeps increasing faster than quadratically with years, with more than one thousand citations from QuSpin publications in 2021 and 2022.

Our most significant investment in equipment is the spin-ARPES laboratory. We welcome Hendrik Bentmann as a new Associate Professor at QuSpin in charge of it. His research focuses on the electronic structure of complex quantum materials. The interplay between electronic topology and many-body effects, such as magnetism, gives rise to new physics and functionalities. His arrival strengthens the research at QuSpin in the topological and magnetic materials field. We look forward to further collaborations with the other experimental groups at QuSpin and the many theorists.

The covid-19 pandemic, with several lockdowns of society, has had a lasting and significant impact on our scientific activity. While the number of research visits and international travel is increasing, we have yet to return to pre-covid-19 activity in this respect. We look forward to the continuity of open society policies and the further nurturing of scientific collaborations and interactions.

Our primary mission is to contribute to the world's scientific endeavors with high-quality research in the field of quantum spintronics.

QuSpin has been fortunate to attract the best talents. Our most significant impact on the future is via the personnel we train. As of now, we have trained eleven post-doctoral researchers and nineteen PhD students. All QuSpin alumni are employed at solid institutions and companies. Additionally, we have supervised more than fifty master students. A record number of six PhD students successfully defended their theses this year.

We have fulfilled our ambitious goal of hiring more than 1/3 of female candidates with QuSpin funding. Gladly, we have also achieved another remarkable aim in our field: 50% of our present master's students are female. We are grateful to the RCN Balance project for supporting improvements in the gender balance at QuSpin.

In short, by midterm, we have met the expectation to a Center of Excellence. We have trained many highly skilled personnel and installed state-of-the-art equipment. We have published many novel findings in the best international journals. We are grateful to our collaborators, the Scientific Advisory Board, our Board, and the NTNU Department of Physics for sustained and long-term solid support.

We look forward to the final years to further develop science in our field to the best of humanity.

Center of Excellence

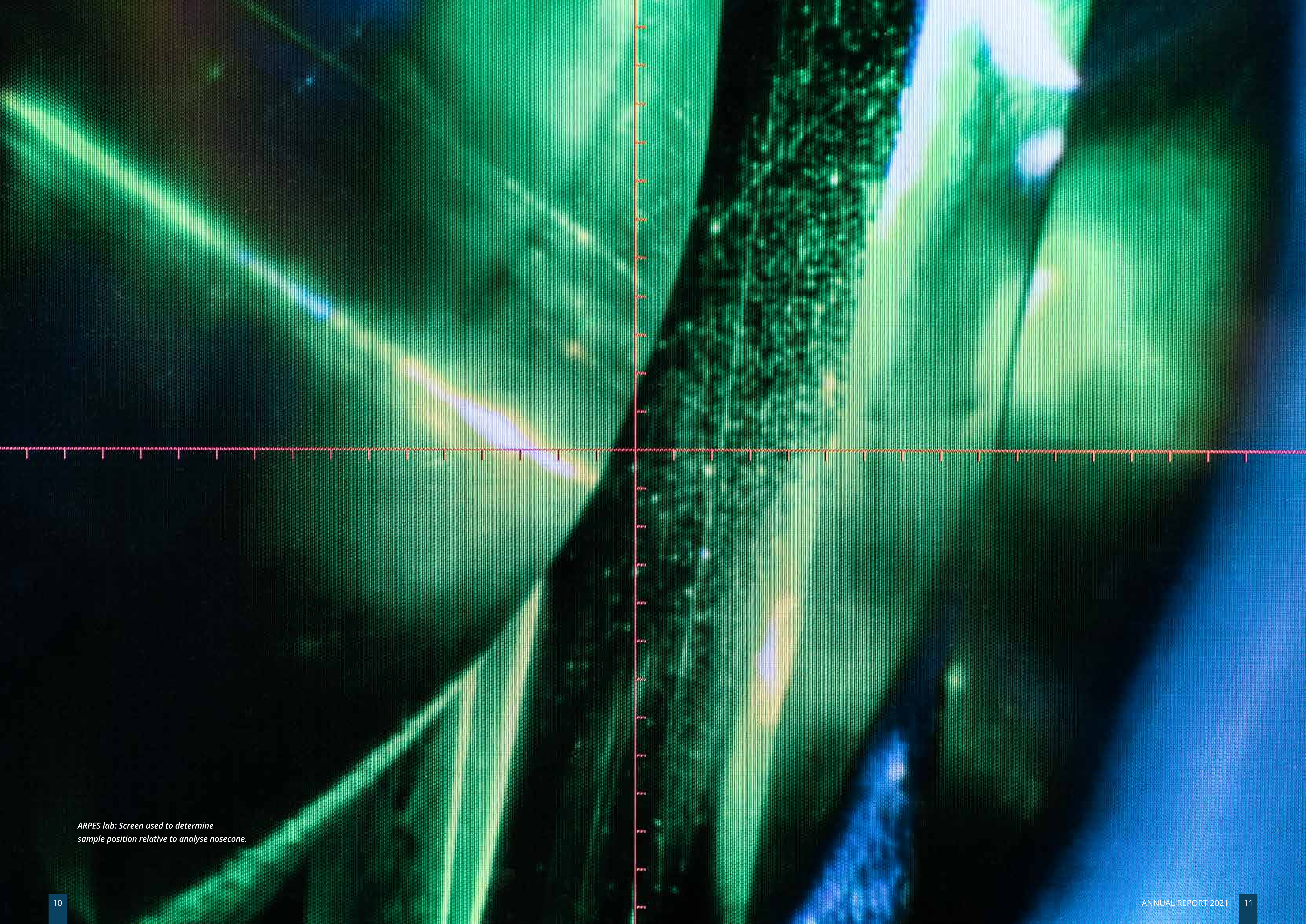
QuSpin, recognized in 2017 as one of ten new Centers of Excellence by the Research Council of Norway, carries the responsibility to provide the resources and space for international researchers, to delve into and unravel the beautiful complexities of condensed matter physics to further our understanding and control of quantum physics in the pursuit of innovations.

To innovate in the field of spintronics, our research center will be receiving funding throughout its ten-year lifetime. QuSpin will receive part of the total funding of 1.5 billion Norwegian Kroner for the Centers of Excellence. We are now halfway in our project and we look forward to the next half period of our research period up till the autumn of 2027.

By the end of 2022, our Center had developed into around sixty-people strong team with members from ten different countries. QuSpin now has eleven permanent professors and associate professors, two senior researchers, four postdocs, twenty-two PhD students, sixteen master's students, and one administrator. In addition, we have one position on twenty five percent as finance controller, two positions on seventeen and twenty percent as Co-Principal Investigators and one professor II position.

As an international research center, QuSpin values its highly professional international advisory board of researchers, as well as an experienced board with senior researchers from NTNU.

In bringing together Norwegian experts with their international counterparts, the Center puts Norway at the forefront of quantum spintronics research. In turn, our research will enable innovative applications.



ARPES lab: Screen used to determine sample position relative to analyse nosecone.

Main Research Themes, Goals and Activities

The principal goal of the Center is to describe, characterize and develop recently identified quantum approaches to control electric signals in advanced nanoelectronics, conceptually different from those existing today.

The research focuses on three judiciously chosen low-dissipation systems: magnetic insulators, topological insulators, and superconductors which correspond to three research themes: insulator spintronics, topological matter, and super spintronics.

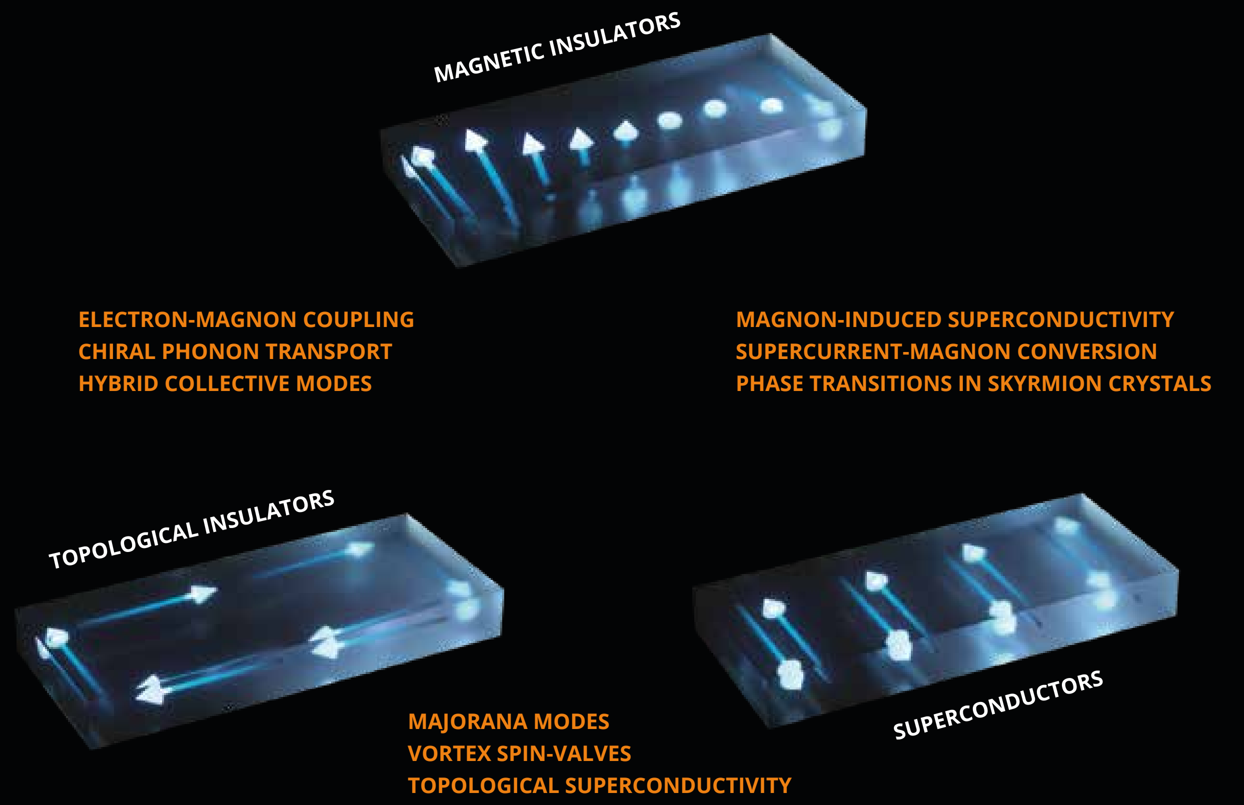
Our unique competitive edge is addressing the ultra-low power innovations by uniting expertise from insulator spintronics, topological matter, and super spintronics. Although these themes are individually exciting, we combine them to generate significant added value.

Electrons can move in free air. In materials, their motion can differ significantly. In metals, the collective flow of the electrons resembles that of particles, but with dramatically altered properties. Their mass, charge, and even spin can be modified. This dressed behavior resembles new particles, so-called quasi-particles, that require new models and new concepts.

We will address how such quasi-particles can convey spin information with exceptional tiny energy losses. Also, we will consider the dynamical evolution of the spin states for high-speed electronics. A supercurrent is a remarkable phenomenon where a current can flow in a supercurrent with no electrical resistance and no energy loss. New material combinations with such properties would revolutionize electronics and have a significant impact on society at large. We will consider how spin can flow via supercurrents.

Successfully meeting these challenges has the potential to transform electronic data transmission, storage, and processing. Ultimately, dissipationless spin transport would solve the problem of energy waste to the environment with potential uses in disruptive technologies.

Overlapping research themes within the different research areas



MAGNETIC INSULATORS: *Magnetic insulators are excellent conductors of spin while forbidding the energy-consuming process of charge transport. In magnetic insulators, the quanta of the spin vibrations can act as new low power dissipation information carriers.*

TOPOLOGICAL INSULATORS: *Topological insulators allow ultra-low dissipation transport of charge and spin at the surface but inhibit lossy processes in the bulk. An important aspect is the exceptionally strong coupling between charge and spin signals.*

SUPERCONDUCTORS: *Superconductors have exactly zero electrical resistance and expel magnetic fields. Cleverly designed nanostructured superconductors in combination with magnetic materials exhibit intriguing new electrical and magnetic phenomena coupling charge and spin information.*

ARNE BRATAAS

Spin Insulatronics

Theme and goal

An electron has a spin in addition to its electric charge. The spin is the source of magnetism. The motion of the mobile charge carriers is the basis of conventional electronics and spintronics. In metals and semiconductors, electric fields induce currents. In magnetic materials, a spin current occurs naturally as well. Spin currents also appear in non-magnetic materials where the spin significantly couples to electron motion.

Spin Insulatronics is profoundly different because there are no moving charges. In magnetic insulators, spin information can, nevertheless, propagate. While electrons are immobile in insulators, another entity conveys information. At equilibrium, the electron spins become ordered. In response to external forces, the ordered pattern of the spins can be disturbed. The disturbance can take forms like waves, spin waves, or other dynamical spin textures.

Controlling electric signals through the deployment of magnetic insulators can facilitate a revolution in information and communication technologies. We aim to determine the extent to which spin in antiferromagnetic and ferromagnetic insulators couples to mobile electrons in adjacent conductors. We will utilize this coupling to control electric signals. We will replace moving charges with magnetic insulators' dynamic low-dissipation coherent and incoherent spin excitations. These features also imply that we can enable unprecedented control of electron-electron correlations. In turn, these features can open the doors toward creating new paths for magnon and exciton condensation, superfluidity, and superconductivity. Furthermore, since spin signals in insulators have extremely low power dissipation, overcoming the limitations can enable low-power technologies such as oscillators, logic devices, non-volatile random-access memories, interconnects, and perhaps even quantum information processing.

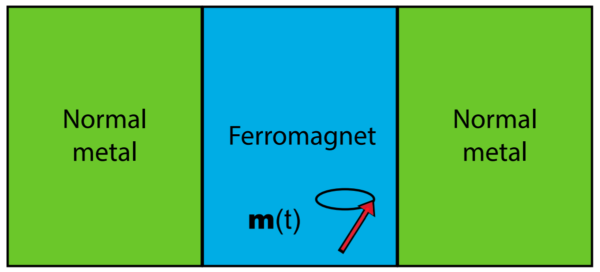
Key questions

We focus on the fundamental challenges facing Spin Insulatronics. Key questions are how spin can transfer from electrical conductors to insulators, how far and how spin propagates in insulators, how we can control correlations that cause new states of matter, and detect these phenomena's signatures.

Activity in 2022

We have contributed to understanding how electrons and holes behave in the antiferromagnetic semiconductor $CuFeS_2$. This material has interesting symmetry properties and will be produced by epitaxial growth techniques in our MBE laboratory led by Christoph Brüne. In another project, we developed a quantum theory of spin transfer torque, spin pumping, and fluctuations. Our results open a path for exploring low-temperature magnetization dynamics and spin caloritronics. We have also theoretically investigated how the simultaneous effects of parametric pumping and spin transfer torque affect the instabilities of individual magnon modes in yttrium iron garnet, a magnetic insulator with exceptionally low damping.

Finally, we have also participated in other developments with partners at QuSpin such as cavity spintronics, thermal squeezing of magnons in antiferromagnets, spin-orbit torques in van der Waals ferromagnets, supercurrents in antiferromagnets, and detection of topological spin textures.



The spin dynamics of a ferromagnet sandwiched between normal metals is influenced by the average and the fluctuations of the charge and spin currents.

ASLE SUDBØ

Topological Quantum Matter

Theme and goal

Topology was originally a branch of mathematics that investigates global geometric properties of objects. These objects could also be more abstract objects defined in a space of mathematical functions. Recently, physics has seen a sharp rise of interest in topological properties of matter in the quantum domain. Quantum topological matter is a branch of physics that studies the properties of materials that have a topological order, which means that their electronic properties are determined by the topology of their underlying electronic wave functions. Examples of quantum topological matter include topological insulators and superconductors, which have potential applications in quantum computing and spintronics. Specifically topologial quantum matter features robust and useful physical properties protected by non-trivial topological properties of the quantum states of the system.

Superfluidity and superconductivity are the phenomena that fluids in the quantum regime may flow without any dissipation. Superconductivity, superfluidity, and magnetism are cooperative phenomena where enormous numbers of degrees of freedom spontaneously self-organize themselves into various ordered states of matter.

Key questions

The overarching goal of our research is to understand how collective effects in quantum systems with topologically protected physical properties, both with and without strong correlation effects, conspire to produce novel and emergent physics. Such effects are of interest from a fundamental physics point of view, and the research is likely to shed light on other areas of physics as well, such as high-energy physics and high-temperature superconductivity. Systems that we study with this in mind are heterostructures of topological insulators and magnetic insulators, topological insulators, and superconductors, and chiral p-wave superconductors.

Activity in 2022

The research carried out in 2022 has focused on defining and computing non-local order parameters for quantum skyrmion-crystals, as well as computing the quantum fluctuations of the ordered state. For classical skyrmions in two-dimensional systems, there exists a topological invariant which counts how many times a spin wraps the unit sphere over the entire two-dimensional space. We have computed an analog of the invariant for quantum skyrmion crystal ground state of a specific spin Hamiltonian involving Dzhyaloshinskii-Moriya interactions and four-spin interactions. We have demonstrated that one may drive the system through quantum phase transitions from one skyrmion crystal to another by varying a specific parameter of the spin-Hamiltonian. Furthermore, we have computed the magnon-spectrum of the systems and found the magnons themselves to be topologically non-trivial. The spectrum has non-trivial Chern-numbers associated with them, which may change as the specific parameter of the spin-Hamiltonian is varied. The impact that the non-collinear spin-texture of the quantum skyrmion crystals have on a superconducting state mediated by the these magnons have been computed in detail. They give rise to topological chiral p-wave superconductivity.

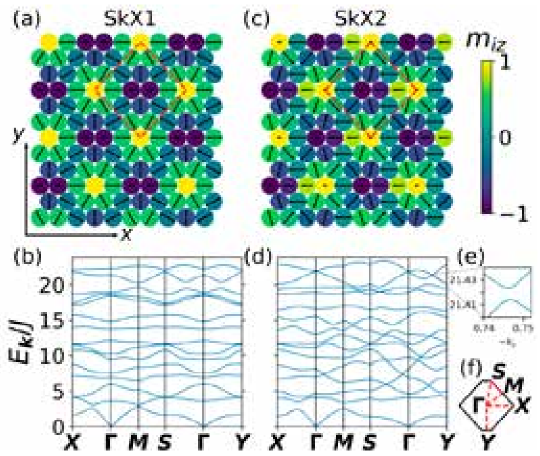


Figure caption: (a), (c) Skyrmion crystal (SkX) ground state shown on a 10 × 12 lattice with periodic boundary conditions. Colors indicate the z component of the spins, while the arrows show their projection on the xy plane. (a) shows the state SkX1, while (c) shows the state SkX2. The parameters are D/J = 2.16, U/J = 0.35, S = 1, K/J = 0.518 for SkX1, and K/J = 0.519 for SkX2. (b) and (d) show the magnon spectrum Ek/J along the path in the first Brillouin zone (1BZ) sketched in (f), for SkX1 and SkX2, respectively.

JACOB LINDER

Superconducting Spintronics

Theme and goal

In classical physics, matter exists as a gas, liquid, solid, or plasma. However, this classification is too crude to capture the fascinating physics that emerges within each of these states. For instance, not all solid states behave the same way. According to quantum physics, various solid materials will behave very differently. Some are magnetic, some do not conduct electric currents, while others can carry currents of not only charge but also a property known as spin. This property is closely related to magnetism and is a fundamental trait of most elementary particles.

It turns out that some materials can conduct electric currents without any energy loss: so-called superconductors. The origin of superconductivity is quantum mechanical, but that does not mean superconductivity only occurs at microscopic length scales invisible to the naked eye. Large chunks of materials can be superconducting, making this phenomenon a macroscopic manifestation of quantum physics. Magnetism is another example of a phenomenon which originates from quantum physics. When different materials such as superconductors and magnets are combined, new physics can emerge that is more than just the sum of properties of the materials. This is one of the motivations behind the field of superconducting spintronics where one studies spin-dependent quantum effects in superconductors.

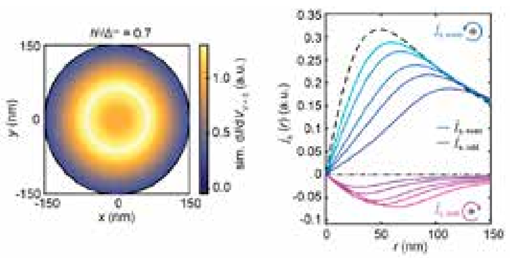
Two main goals guide our research. The first one is to discover new quantum phenomena that transpire when combining superconductors with materials that have fundamentally different properties, such as magnetic ones. Secondly, we focus on discovering phenomena that are relevant to the development of cryogenic information transfer, generation, and storage based on superconductors. This is closely related to the transport of charge, spin, and heat in hybrid structures. We use a variety of analytical and numerical tools to address the research questions above, depending on which method is the most appropriate for the system at hand. Some of our theoretical approaches include lattice models, quasiclassical Keldysh theory, Green function techniques, scattering theory, and Landau-Lifshitz-Gilbert phenomenology.

Key questions

The main research problems we are focusing on solving are related to the functional properties of materials and how they can be controlled and altered by combining several materials or by applying external stimuli. For instance, is it possible to use magnetic materials to control when superconductivity appears and even enhance its properties? How can one use superconductors to generate and detect transport of not only charge, but also other degrees of freedom such as spin and heat, with minimal energy loss? Finally, we are interested in understanding the quantum dynamics of various types of long-range order in solid-state systems when quenches are applied in interaction parameters, to see if novel meta-stable quantum phases can be accessed.

Activity in 2022

One of our research highlights in 2022 was the prediction of spin-polarized Cooper pairs propagating a long distance through antiferromagnetic materials. We also solved the long-standing experimental puzzle regarding the suppression of the superconducting critical temperature by proximity to antiferromagnets. We have collaborated with experimentalists to observe magnetic-state dependent thermoelectric effects in superconducting spin-valves. Other research activity includes the prediction of a strongly increased Pauli limitation in flat-band superconducting systems, spin-pumping using rotating electric fields, and a collaboration with experimentalists demonstrating temporally non-local Cooper pairs in thin-film aluminium. Our publications in 2022 include four papers in PRB Letters and two papers in PRB. In addition, two papers have been submitted to PRL, one to RMP, and one accepted in Science Advances.



Left: Real space simulation of novel vortex structure obtained using in-plane magnetic fields in thin-film superconductors. Right: Supercurrent density contribution from conventional and odd-frequency Cooper pairs.

HENDRIK BENTMANN

Spectroscopy of Quantum Materials

Theme and goal

The recent decades have seen the rise of modern information and communication technologies, largely based on the use of semiconductors in transistors and integrated electronic circuits. This era is sometimes referred to as the „silicon age", highlighting the importance of the material silicon in this context. The properties of silicon are well understood on fundamental grounds. However, there are classes of materials whose physical behaviour is vastly more complex and less understood, including superconductors, magnets, and topological systems. In these „quantum materials" the quantum-mechanical nature of the electrons and their mutual interactions come to the forefront and remain manifest over a wider range of energy and length scales. Researchers envision that proper control of these quantum effects and resolving some of their puzzles could enable new technologies beyond the silicon age. Understanding the physics of quantum materials is challenging, however, and involves the development and application of sophisticated experimental and theoretical techniques.

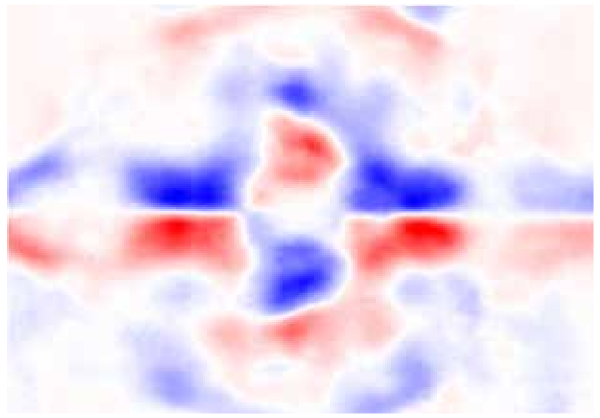
We use a method called spin- and angle-resolved photoelectron spectroscopy (spin-ARPES) to investigate magnetic and topological materials. Spin-ARPES is based on the photoelectric effect, i.e. the excitation of photoelectrons at a material surface upon irradiation with monochromatic light. The effect has long been known and constitutes one of the key observations that paved the way from classical electrodynamics to quantum mechanics. Use of modern spectrometers and light sources allows us to study the spatial, angular and spin distributions of photoemitted electrons as well as their dependence on energy and polarization of the exciting light, providing detailed information about electronic and magnetic properties. With this, our goal is to contribute to the discovery and to a refined microscopic understanding of quantum states in new and complex materials.

Key questions

Our primary focus lies on the investigation of electronic states with so-called topological properties which give rise to unusual spin textures in momentum space. We are interested in how topological properties and spin textures are related to or modified by ferromagnetic or antiferromagnetic order, specific crystalline symmetries, quantum confinement in atomically thin crystals and proximity coupling in heterostructures. Spin-ARPES allow us to directly address these points experimentally. In the coming year, we are planning to upgrade the spin-ARPES setup in our laboratory with a UV laser light source to enable higher resolution and count rates as well as new contrast mechanisms, such as dichroism. We perform complementary experiments at international synchrotron radiation facilities and collaborating laboratories.

Activity in 2022

The ARPES group is now navigating through a transition period. Two new PhD students started working in the lab in late 2022, one from QuSpin and one from FACET (co-supervised). Initial steps in these projects were carried out. Furthermore, we are looking forward to a new postdoc and a new head engineer to join the group in early 2023, as well as another PhD student in late 2023. Plans for upgrading the spin-ARPES setup with a UV laser light source were kicked off. As a first experimental highlight, we performed synchrotron-based measurements of the electronic structure in a chiral topological semimetal.



Circular dichroism in the angular distribution (CDAD) of photoemitted electrons for a topological semimetal, probing the chirality of Weyl nodes in the band structure.

CHRISTOPH BRÜNE

Molecular Beam Epitaxy of Antiferromagnets

Theme and goal

Access to high-quality magnetic materials is essential for spintronics research. Especially magnetic thin films are of great interest. These are layers of magnetic materials with thicknesses in the nm range. We are developing thin film synthesis of magnetic materials with large potential for spintronics research and applications.

To do this, we rely on a technique called molecular beam epitaxy. This technique uses an ultra-high vacuum environment to guide atoms or molecules onto a target, where a crystalline layer will grow under the right conditions. Using this method, we can create high-quality crystals with thicknesses down to a single atomic layer. It is also possible to combine different materials in complex layer structures to create new physical properties and control them in detail. Furthermore, we can also create nano-objects like nano-wires and quantum dots using molecular beam epitaxy.

Key questions

Our first key project area is the growth of so-called antiferromagnetic semiconductors. These materials combine the potential for new spintronics applications with the possibility to manipulate the material properties using electric fields (similar to today's semiconductor technology). This will enable the integration of established semiconductor techniques and spintronics applications.

Here we are currently concentrating our efforts on the growth of CuFeS2, an antiferromagnetic semiconductor with a very high Néel temperature of 823 K. This work is done in collaboration with Arne Brataas' and Mathias Kläuis' group in QuSpin. We are also collaborating with Morten Kildemo and Magnus Nord for optical and structural studies of our thin films.

Helimagnetic systems are the group's second research area. These materials are very interesting for their complex magnetic structures, based on a spiraling (helical) order of the spins in the material. This includes so-called 'Skyrmions', stable magnetic whirls inside the material. Skyrmions are promising for their potential as nano-objects for future low-energy memory devices. We are currently developing the growth of materials in the Fe-Sn and Mn-Sn family of materials. These materials are known for their Kagome lattice type spin structures and are hosting helical and skyrmionics states. These investigations are conducted in close collaboration with Dennis Meiers' group, with two PhD candidates shared between the two groups.

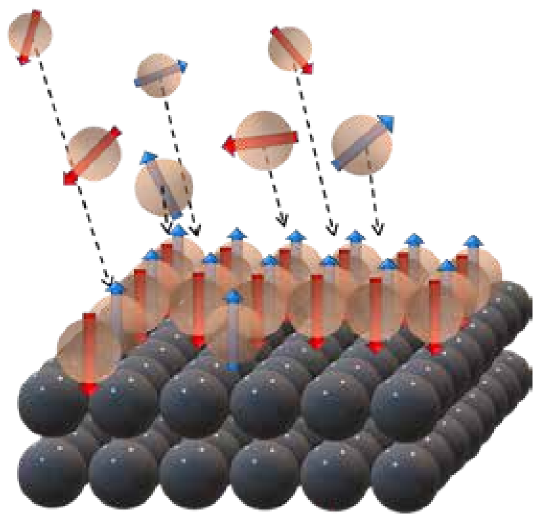


Illustration of molecular beam epitaxy growth of an antiferromagnetic layer on a non-magnetic substrate.

Activity in 2022

The central theme for 2022 was growth development and improvement. After the trying pandemic period, we have finally had a well working growth system for most of the year. We are now routinely growing CuFeS2 thin films and are successfully investigating their structural and optical properties. We have established the high crystalline and optical quality of these films using X-ray diffraction, transmission electron microscopy and ellipsometry.

For the helical materials we have established growth of both Fe3Sn2 and Mn3Sn. Both materials are routinely grown as thin films (though surface coverage is so far not optimal). Reflective-high-energy-diffraction on the other hand shows signatures of highly ordered, very flat surfaces during growth and X-ray diffraction establishes good crystalline quality.

JEROEN DANON

Spin-based Quantum Computation

Theme and goal

The quest for the optimal physical qubit (it should be stable, controllable, and scalable) is at full speed, and by now the research has been narrowed down to a handful of very promising approaches. My research is theoretical, but focuses on practical aspects of such qubit implementations, usually in close collaboration with experimentalists.

A large part of my work is in the field of spin qubits in semiconductor quantum dots (small potential traps inside a semiconductor), where the basic idea is to use the spin degree of freedom of localized electrons as a qubit basis. Attractive features of such qubits are that they are small, fast, and potentially easily scalable. Since they are very similar in design to regular microchip transistors, one could imagine leveraging industrial fabrication techniques to massively scale up spin-based quantum processors.

A promising recent development in the field is a successful shift from GaAs-based spin qubits to devices that are hosted in group-IV materials, such as Si and Ge. An intrinsic problem with GaAs is that both Ga and As atoms carry finite nuclear spin, which results effectively in randomly fluctuating magnetic fields acting on the qubit spins, which causes fast qubit decoherence (loss of the quantum aspect of the information). Both Si and Ge can be isotopically purified to be nearly nuclear-spin-free, and are thus much better host materials in that sense. Practical problems with the more complex conduction-band structure in Si and Ge turned out to be avoidable by using the spin of *holes* ("missing" electrons) in the valence band as quantum information carriers. This shift has yielded qubits that operate below the fault-tolerant threshold.

Key questions

Most problems my group is working on are related to questions such as: How can we further improve qubit initialization, control, or read-out in a specific setup? What processes dominate qubit decoherence? How can we further reduce the effect of these processes? How can we achieve a significant scale-up of spin-qubit devices, including coherent qubit-qubit coupling between distant qubits?

Activity in 2022

Currently, one of the core activities of my group is developing a detailed understanding of the properties of the valence-band holes in materials such as Si and Ge. Due to the underlying *p*-type nature of their wave function, the spin and orbital degrees of freedom of confined holes can become strongly mixed, resulting in complex spin dynamics that depend intricately on the interplay between the applied magnetic field, electric field, and the band structure itself.

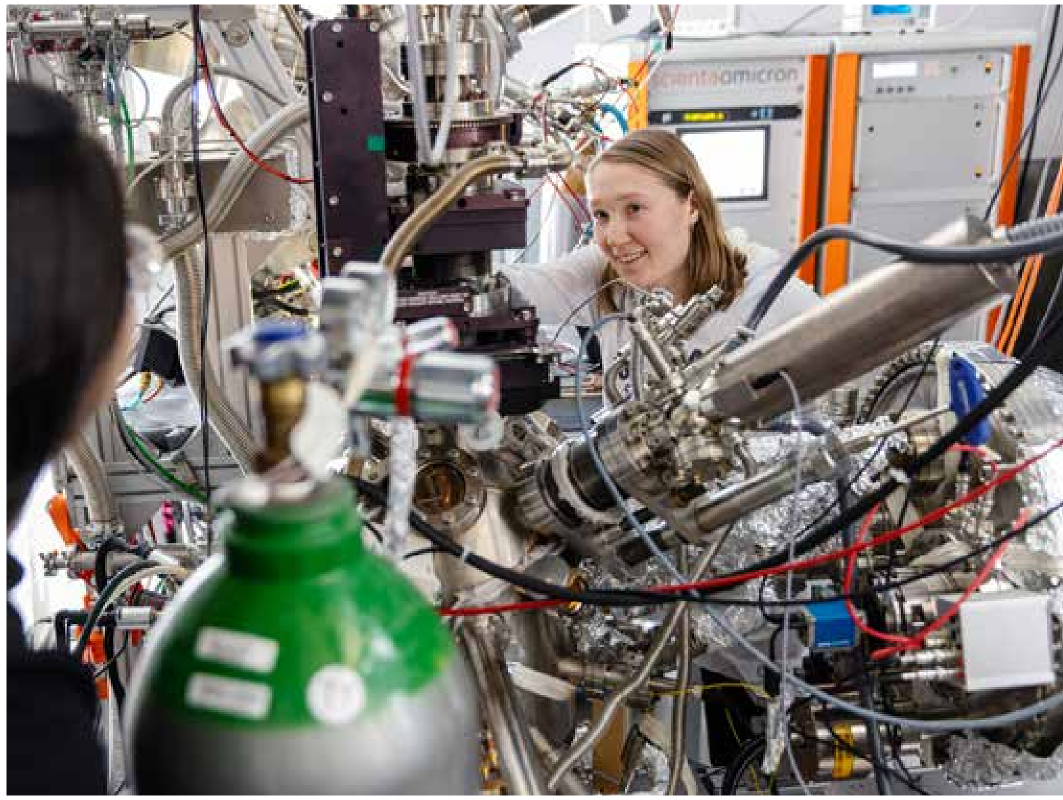
Another direction of research in my group is to try to solve the problem of the nuclear spins in GaAs in some other way. This includes investigating protocols for actively monitoring the fluctuations of the nuclear fields, using adaptive Bayesian estimation methods combined with neural-network-based machine learning techniques.

EXPERIMENTALISTS AT WORK

PhD students and a Postdoc at work in the MBE lab and the ARPES lab.

MBE lab

ARPES lab



ARPES lab

JOHN OVE FJÆRESTAD

Frustrated Quantum Antiferromagnets

Theme and goal

Our group's research centers around lattice models of quantum antiferromagnets, especially models with competing (aka "frustrated") interactions. In combination with strong quantum fluctuations, frustration may prevent magnetic order and instead lead to other, magnetically disordered, phases that possess more exotic types of order that are of great fundamental interest.

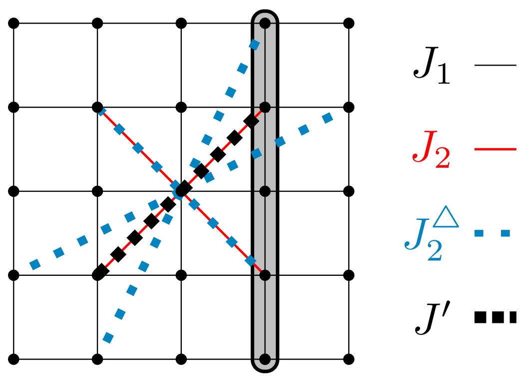
Of particular interest are phases known as quantum spin liquids, whose order is not described by broken symmetries but may instead be of a topological nature. In recent years, new materials have been discovered which exhibit evidence of unconventional behavior pointing towards spin-liquid physics.

In recent years it has also become clear that various concepts and quantities originating in quantum information theory, like entanglement entropy and fidelity, may be very useful for characterizing quantum many-body phases and the quantum phase transitions between them. Different types of order may give rise to characteristic "signatures" in such quantities and their behavior as a function of various parameters.

The overall goal is to get a better understanding of the "zoo of phases" that may arise in frustrated quantum antiferromagnets, and contribute towards their description and classification.

Key questions

Key questions include whether/where quantum spin liquids arise the phase diagram of various lattice quantum spin models, what types of quantum spin liquids can arise, and how various types of order can manifest themselves through signatures in quantities like entanglement entropy (including both orders that are and are not described by broken symmetries).



Examples of model interactions for calculations of entanglement entropy of magnetically ordered frustrated quantum Heisenberg antiferromagnets (subsystem in grey).

ERIK WAHLSTRÖM

Local and Global Magneto-dynamic Properties of Oxides

Theme and goal

Our primary theme is to probe and understand excitations in the charge, spin and lattice, and their interactions at the atomic scale. Our primary method is through developing excitation spectroscopy techniques, primarily scanning-based probe techniques and other experiments that provide insights into the fate of charge and spin in materials.

Our short-term goal is to explore the magneto-electronics and magnonics of oxide ferromagnets and antiferromagnets. In a more applied context, the long-term goal is to understand and control coupling in the thermal energy scale in order to contribute to the use of thermal energy to communicate information. The longer-term goal on the method side is to develop STM-based point-contact techniques to explore mesoscopic and magnetodynamic physics at a very local scale.

Key questions

We primarely study the excitations and coupling between magnons, phonons and charge carriers at an energy scale that ranges from sub-thermal energies to electron volts. In the spin domain, the prime motive is to understand magnons, and the expression in the form of interacting and propagating magnons and their interaction with charge and phonons.

In the phonon regime, we are interested in understanding size and material control and tunability in coupling to the charge and spin excitations.

We are primarily investigating model systems in oxide materials, developing an understanding of perovskite-type ferromagnets and antiferromagnets, mainly seeking collaboration with groups on the material synthesis side to address our key questions.

Activity in 2022

We have started up our project on phon-magnon coupling in oxide heterostructure. This is an internationally collaborative effort where THz imaging (Stefano Bonetti, Stockholm), PEEM imaging of excited structures (Ferran Macia, Barcelona) and development of point contact spectroscopy (NTNU and Toshu An, Kanasawa) will be used to probe structures grown in collaboration with the oxide electronics group at NTNU. Travis Gustafsson is the first to join our team as PhD student in the project with a main aim to perform PEEM imaging and electric measurements on combined Surface acoustic wave and magneto dynamic wave mixing. He has also participated in dynamic PEEM experiments at ALBA. We also worked on initiating the other parts of the project in close collaboration with Prof. Thomas Tybell in the electronics department.

DENNIS MEIER

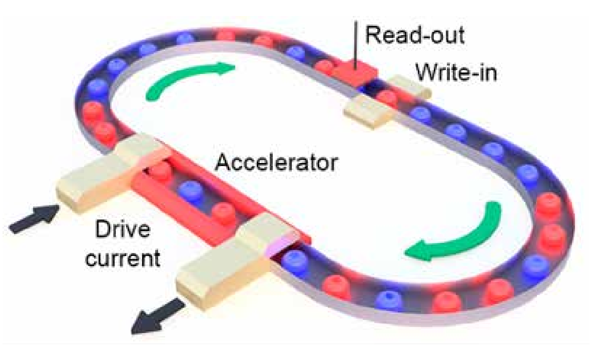
Topological Spin Textures

Theme and goal

Topological spin textures, such as magnetic skyrmions and domain walls, are a rich source for emergent physical phenomena and promising functional nanoscale systems for future technologies, enabling conceptually new approaches towards low-energy information processing and data storage. Application opportunities range from logic gates and memory devices to unconventional computing and sensing.

Our research studies the fundamental physics that give rise to the unique properties and dynamical responses of topological spin textures in ferroic materials with spontaneous magnetic long-range order. We are particularly interested in the unusual local responses of these special magnetic defects, their scaling behavior and how they can be created on demand, controlled, and read out. For this purpose, we apply different advanced microscopy and nano-structuring tools which allow us to investigate the topological defects spatially resolved in device-relevant geometries.

The goal of our research is to understand and utilize the emergent functional phenomena associated with topological spin textures, developing current device paradigms into new realms of magnetism.



Ring-shaped racetrack memory with accelerator, where skyrmionic bubbles of opposite helicity (illustrated by red and blue colors) are used to encode binary data.

Key questions

Many developments in the field have occurred only recently, and it remains an open question how skyrmions, dislocations, and other topological spin structures form in confined media and to what extent their topology-driven interactions distinguish them from the surrounding material. We tackle these questions and gain new knowledge about the underlying physics by applying different microscopy and nano-structuring methods, such as magnetic force microscopy (MFM) and focused ion beam (FIB).

For example, we use FIB to shape materials of interest into device-relevant structures. Based on these structures, we study e.g. the impact of reduced physical dimensions on the magnetic order and how electrical currents and magnetic fields control the position and movement of individual spin textures. Ultimately, we want to understand the new degrees of flexibility topological spin textures can offer and demonstrate new opportunities that arise for future applications, including Green-IT (i.e. low-power technologies) and modern concepts for unconventional computing.

Activity in 2022

One of the key achievements in 2022 was our successful patent application for a new type of *Spin Texture Storage Device*. In this device, dipolar skyrmionic bubbles are used as binary information carriers in a ring-shaped racetrack, where they are driven by the so-called *accelerator*, promoting reduced energy consumption. The patent was presented at the Nordic Innovation Fair, and we are currently in the process of acquiring funding to work towards a functional proof-of-concept device. In addition, we collaborate with the team of Christoph Brüne to develop new thin film materials that can simplify the production process. With Alireza Qaiumzadeh and Arne Brataas, we explored other device concepts (published in Nano Letters) and initiated new research activities in the field of unconventional computing together with Mathias Kläui.

SOL H. JACOBSEN

Triplet Spintronics

Theme and goal

Superconducting spin-polarized triplets carry coherent quantum information. A component of their correlation does not decay in either ferromagnets or superconductors, even with impurities. This makes them a primary candidate for low-dissipation information transport in spintronics. We examine the interplay of magnetism and superconductivity in emerging spintronic systems using theoretical and numerical techniques.

Key questions

Our research considers atypical geometries and model setups for examining the conversion mechanisms, manipulation and detection of superconducting singlets and triplets in spintronic devices, including magnets. We primarily consider the effect of curvature and/or strain, as well as cavity-mediated effects, which may enable new superconducting spintronic device design and control.

Activity in 2022

Following our surprising discovery that geometric curvature in a magnet can reverse the charge current direction in SFS Josephson junctions [1], we showed that it can also control the superconducting transition [2]. This provides a new way of designing a superconducting spin valve.

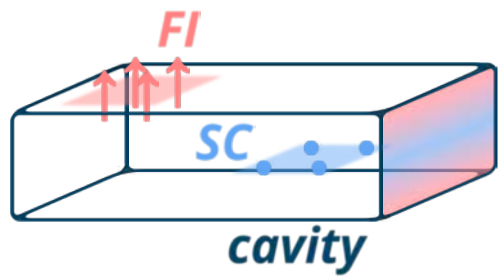
Continuing our long-term collaboration with Morten Amundsen at NORDITA, we showed that interband pairing in spin-split two-band superconductors can exhibit re-entrant superconductivity, and substantially enhance the upper value of the critical magnetic field [3].

Andreas Janssønn and Henning Hugdal completed an intricate derivation of the quantum details of the coupling between a superconductor (SC) and ferromagnet (FI) in a cavity, to appear as Editors' Suggestion in Phys. Rev. B [4]. We showed a novel remote sensing scheme, where the superconducting transition can be detected at a remote ferromagnet, through a change in its anisotropy field. It demonstrates micrometre-range coupling between the SC and FI, while allowing them to be subjected to different drives and temperatures, and suggests new possibilities for remote sensing in the future.

This year I was very happy to give four invited talks about the role of geometric design in superconducting spintronics. These were at the Institute of Physics colloquium on "Spintronics with Geometric Design" in Manchester, the QuSpin International Conference, the inaugural Korea-Nordics collaboration workshop on quantum materials in Stockholm, and the "Geometric Resources for Quantum Engineering Workshop II" in Seville. I met many new colleagues who are excited about geometric effects, and I look forward to lots of new discussions in the future!

Serving in the project group of the QuSpin Balance Project through 2022, and the associated participation in NFR's national Balance Program 2021-2022, have provided many useful insights into the broad range of theory and practice of diversity training and awareness. We also increased our group's visibility by establishing a website and a Twitter account.

The year's highlights for the group were crowned by the successful defence of Andreas Janssønn's PhD thesis, and Mariell Breivik and Alv Johan Skarpeid's master theses. We wish them all well onwards! We welcome new master students Eirik J. Høydalsvik and Magnus Skjærpe, and we are lucky to continue collaborating with Alv as he studies for his PhD degree in E. Folven's group at NTNU.



Cavity-mediated interactions between a ferromagnetic insulator and a superconductor suggests new methods for remote sensing [4]. Fig. by A.T.G. Janssønn.

[1] Salamone, T. et al, PRB 104, L060505 (2021)
[2] Salamone, T. et al, PRB 105, 134511 (2022)
[3] Salamone, T. et al, arxiv: 2208.04338
[4] Janssønn et al, to appear in PRB (Editors' Suggestion); Arxiv: 2209.09308

ALIREZA QAIUMZADEH

Emergent Phenomena in Quantum Matters

Theme and goal
Our work is focused on several research themes, including Quantum spintronics and magnetism, including topics such as topological magnetic textures, superconducting spintronics, and neuromorphic spintronics; quantum transport phenomena; Topological phases of matter and quantum matter; ultrafast and nonequilibrium phenomena; and Quantum field-theory in condensed matter physics and many-body effects.

Our goal is understanding, probing, and engineering emergent and exotic phenomena in quantum materials, such as two-dimensional (2D) magnetic materials, and 2D and 3D topological materials. We are also interested in investigating potential applications of these phenomena in quantum technology, like neuromorphic spintronics and quantum information.

Novel quantum materials have exotic and interesting behaviours. For example, in 2D systems, quantum fluctuations and interactions are usually strong and cannot be neglected. On the other hand, in novel 3D topological materials, like Weyl and Dirac semimetals, emergent low-energy massless quasiparticles provide a testbed for investigation of new phenomena beyond conventional relativistic quantum field theory and the Landau Fermi liquid paradigm.

Developing theories to understand and uncover exotic equilibrium and nonequilibrium states of novel quantum materials with an ultimate application beyond the state-of-the-art quantum devices is among our goals.

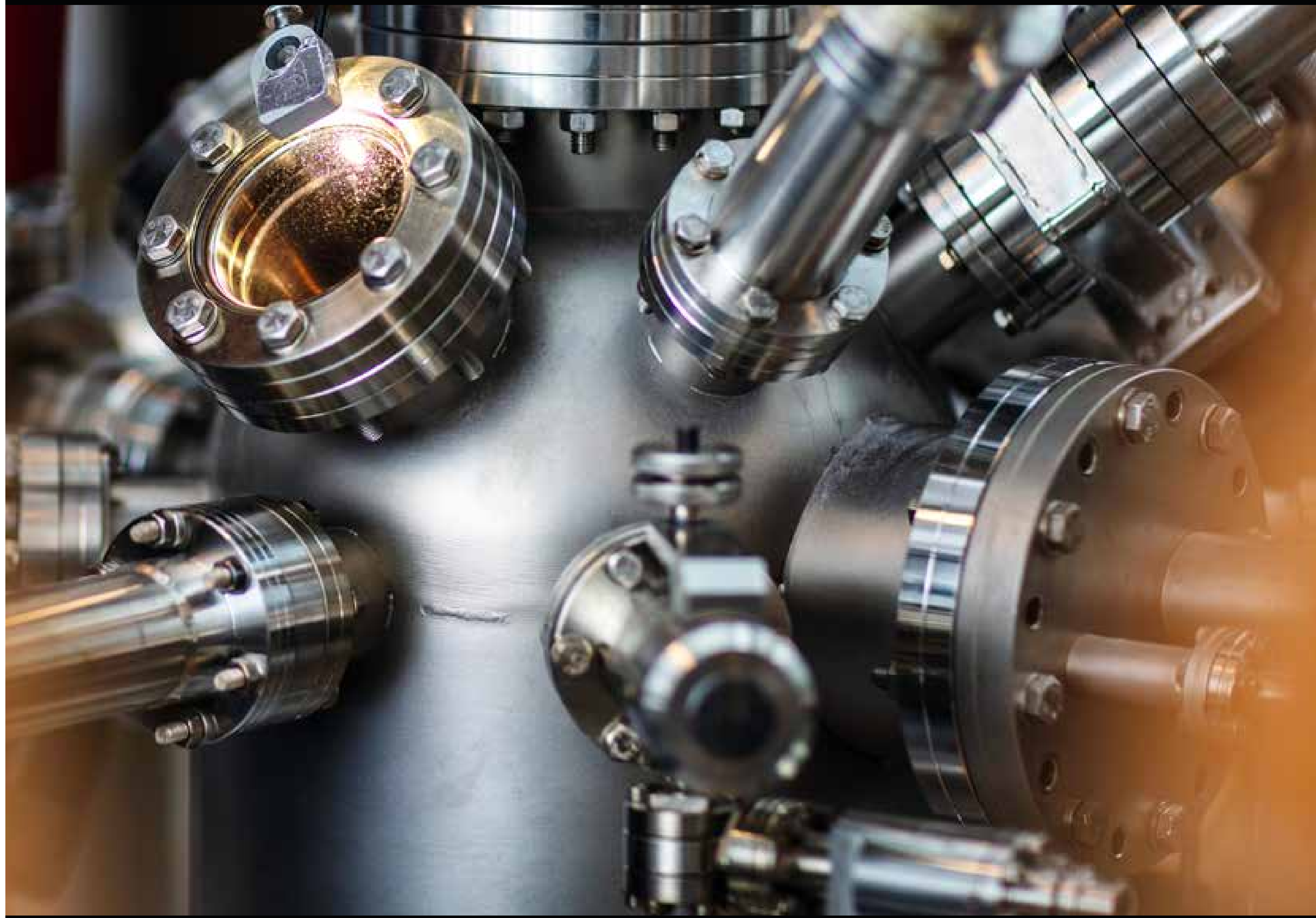
Key questions
Interplay between spin, charge, and lattice degrees of freedom; hybridization and scattering between different quasiparticle and collective excitations such as magnons, spinons, phonons and plasmons; in equilibrium and nonequilibrium, lead to emerging phenomena in both real and momentum spaces.

Microscopic understanding of these phenomena is a challenging problem in theoretical physics for which we need to develop and apply sophisticated analytical and advanced numerical techniques. We are interested in studying the effect of quantum and thermal fluctuations in stabilizing different topologically nontrivial magnetic phases and exotic spin transport in novel 2D spin systems. Developing theoretical and computational frameworks beyond conventional approaches for describing these phenomena on a microscopic level is an important topic in our group.

Activity in 2022
In 2022, we continued our collaboration with Arne Brataas as our main internal collaborator and several other world-leading experimental and theoretical groups. In collaboration with the experimental group of Prof. Kazuya Ando in Japan, we found emergence of tunnelling spin-orbit torques at magnetic-metal/semimetal heterojunctions. In collaboration with Alberto Cortijo and María Vozmediano in Spain, we investigated the fingerprint of conformal anomaly in tilted Weyl semimetals.

In another achievement, our PhD student Verena Brehm has uncovered the underlying mechanism of spin transport in easy-plane antiferromagnetic insulators based on a new coherent beating oscillation mechanism. We have also proposed a non-volatile leaky integrate-and-fire neuron based on antiferromagnetic domain walls. Our postdoc Marion Barbeau has, in collaboration with Mikhail Katsnelson and Mikhail Titov in the Netherlands, developed a new quantum kinetic formalism for nonthermal magnons excited by hot electrons in an antiferromagnetic metal under strong laser irradiation. In collaboration with our postdoc visitors, Mahroo Shiranzaei and Roberto Troncoso, we found thermal squeezing and nonlinear spectral shift of magnons in 2D antiferromagnetic insulators.

Finally, thanks to NTNU Nano, the first version of our open-source software for AFM simulation, developed by our former students Even Aksnes and Viroshaan Uthayamoorthy, was released in 2022.



ARPES lab: Scanning tunneling microscopy (STM)

International Partners and Research Network

We are continuing the long-term collaboration with our Co-Principal Investigators and their groups, Professor Mathias Kläui at the Institute of Physics at Johannes Gutenberg University of Mainz in Germany, and Professor Rembert Duine at the Institute for Theoretical Physics at the University of Utrecht in the Netherlands.

Professor Rembert Duine

Professor Rembert Duine is a leading theoretician scientist in the quantum many-body physics of spin transport and spin excitations, and a Professor II at QuSpin. Landmark publications by Rembert Duine and his collaborators have led to the opening of new sub-fields of physics, such as magnetic skyrmion spintronics, antiferromagnetic spintronics, and cold spintronics. The insights gained in these developments give QuSpin complementary expertise in theoretical developments on magnetic insulators and topological matter. Most of the collaborations over the past year have focused on quantum magnonics, involving also the group of Professor Kläui, and on interactions in ultrapure conductors.

Professor Mathias Kläui

Professor Mathias Kläui is a leading experimental scientist, and a Professor II at QuSpin. A central theme of the collaboration has been spin transport in antiferromagnetic insulators, where we have established fruitful synergies between experimental and theoretical developments. Combining the work of young and dynamic experimentalists in Trondheim and Mainz, with the support of our excellent theory activity, QuSpin is taking its experimental activity to the next level. In particular, the collaboration with JGU Mainz gives QuSpin access to state-of-the-art materials growth, characterization and transport measurements. Recently, exciting predictions on magnetic 2D materials have been corroborated in joint activities between Mainz and Trondheim. To strengthen our collaboration, joint PhD work where one student from Mainz will spend some time in has recently been initiated with further support from a project that we have jointly applied for.

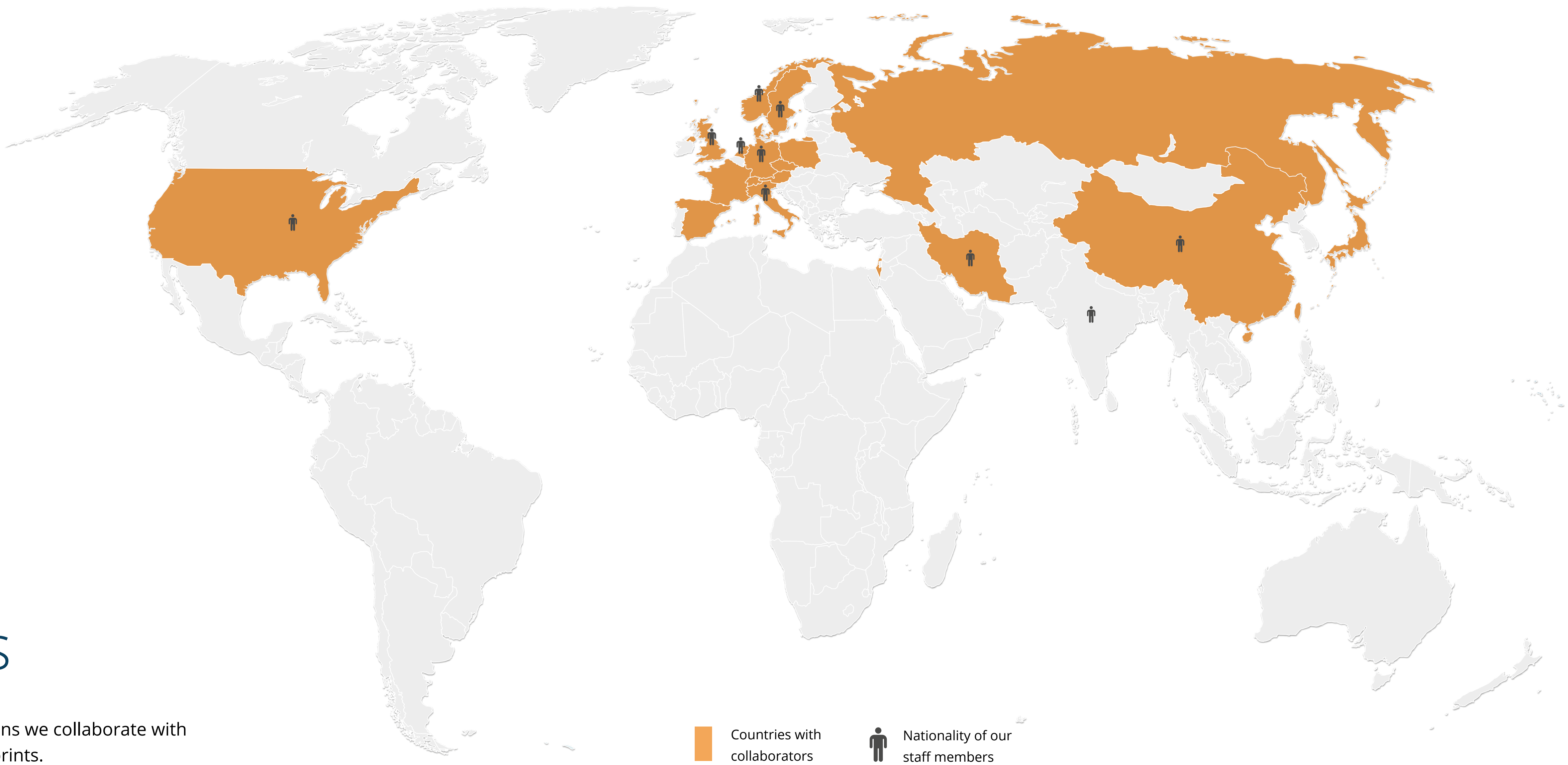
The QuSpin Center is grateful for its opportunities to host visiting researchers that allow for interactions on a personal level, bolstering the professional work and exposure to new, ongoing, and past projects. In addition, we collaborate with internationally leading theoretical and experimental groups in many places around the world (See map next page).

THE RESEARCH TEAM OF PROFESSOR REMBERT DUINE *at the Institute for Theoretical Physics (ITP) is part of the Department of Physics of the Science Faculty of Utrecht University. The ITP hosts over 10 faculty members and 70 members including junior researchers in total.*

THE RESEARCH TEAM OF PROFESSOR MATHIAS KLÄUI *is part of the Institute of Physics at Johannes Gutenberg-Universität Mainz. The Kläui lab has 12 faculty members and 48 members including junior researchers and staff in total.*

Collaborators

The list below is an overview of the institutions we collaborate with as co-authors on published papers and preprints.



AUSTRIA
Graz University of Technology, Graz

CZECH REPUBLIC
Czech Academy of Sciences, Prague

CHINA
Central South University, Changsha
China Academy of Engineering Physics, Beijing
University of Chinese Academy Sciences, Beijing

DENMARK
University of Copenhagen, Copenhagen

FRANCE
Nancy Universitè, Nancy
Universite Grenoble Alpes, Saint-Martin-d'Hères
Universite Paris-Saclay, Saint-Aubin
Université de Strasbourg, Strasbourg
Unité Mixte de Physique CNRS/Thales, Palaiseau

GERMANY
Fritz-Haber-Institute of the Max-Planck Society, Berlin
Johannes Gutenberg University Mainz, Mainz
Karlsruhe Institute of Technology, Karlsruhe
Leibnizs Institute, Dresden
TU Kaiserslautern, Kaiserslautern
Technical University of Munich, Munich
University of Augsburg, Augsburg
University of Cologne, Cologne
University of Konstanz, Konstanz
University of Regensburg, Regensburg
University of Würzburg, Würzburg
Walther Meissner Institute for Low Temperature Research, Munich

IRAN
Institute for Research in Fundamental Sciences, Teheran
Institute for Advanced Studies in Basic Sciences, Zanjan

ISRAEL
Hebrew University of Jerusalem, Jerusalem

ITALY
University of Genova, Genova
Universitá di Milano-Bicocca, Milan

JAPAN
RIKEN Center for Emergent Matter Science, Saitama

THE NETHERLANDS
Radboud University, Nijmegen
Utrecht University, Utrecht
University of Groningen, Groningen

NORWAY
University of Oslo, Oslo

POLAND
Polish Academy of Sciences, Warzaw
Adam Mickiewicz University, Poznań

ROMANIA
Technical University of Cluj-Napoca, Cluj-Napoca

RUSSIA
Russian Academy of Sciences, Moscow

SPAIN
Instituto de Física Fundamental, Madrid
Donostia International Physics Center, Donostia-San-Sebastian
Universidad Autónoma de Madrid, Madrid
Instituto de Ciencia de Materiales de Madrid (CSIC)

SWITZERLAND
ETH Zürich, Zürich

SWEDEN
KTH Royal Institute of Technology, Stockholm
Uppsala University, Uppsala

UK
Cambridge Graphene Centre, Cambrigde
Hitatchi Cambridge Laboratory, Cambrigde
Loughborough University, Loughborough
University of Cambridge, Cambridge
University of York, York
Swansea University, Swansea
University of Central Lancashire
University of Edinburgh

US
Cubic Carbon Ceramics, Huntingtown
Harvard University, Cambridge, MA
University of California, Riverside
University of California, Berkeley
University of Central Florida, Orlando
University of Chicago, Chicago
Massachusetts Institute of Technology, Cambridge
University at Buffalo, State University of New York

Research Training of our PhD Students and Postdocs

We wish to train the next generation of researchers within our field so that they can take on leadership for new projects of their own, as well as gain experience by co-supervising our PhD students and Master's students.

The blackboard is often used to explore scientific ideas and solutions to a problem.

Group dialogue often takes place in a relaxed environment in our lunchroom.

Discussing scientific challenges.

We give a range of workshops and seminars at the Center. At the seminars the speakers present their work, share ideas and discuss the challenges they face. Our regular Journal Club provides training in presenting a scientific article and its essence for discussion. These are valuable experiences in the process of their work and in writing articles for publication as well as giving talks at international conferences and workshops.

In addition, guest researchers are giving interesting talks. This gives an opportunity to extend our understanding of ongoing work by colleague researchers and opportunities for fruitful collaborations.

We also have a self-organized Idea Forum for the younger researchers, where projects, ideas, and research challenges are shared, stimulating collaboration across both the theoretical and experimental fields, as well as between PhD students, postdocs and senior researchers.

The professor's and senior reseracher's teaching, supervision, and curriculum is still the primary source for each PhD students' research training. However, we see that all the other activities have a significant added value.

Launching the QuSpin Mobility Grant

Encouraging our PhD students to seek international research experience, broaden their cultural outlook and extend their network.

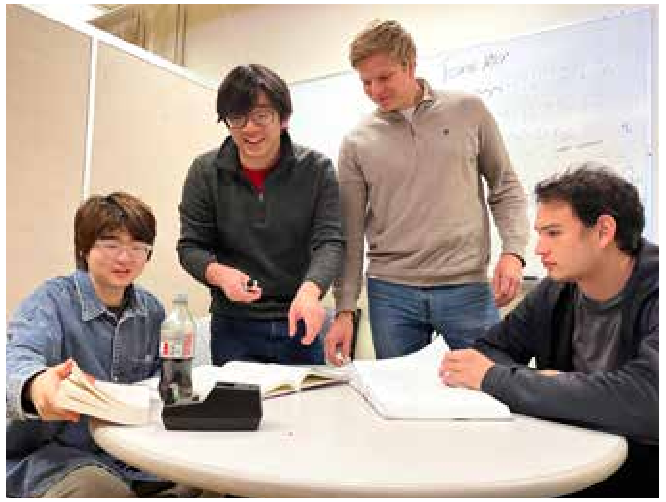
This article is based on interviews with PhD students Lina Johnsen Kamra and Bjørnulf Brekke, facilitated by Karen-Elisabeth.

The QuSpin Mobility Grant
In 2022 we established the QuSpin Mobility Grant which our PhD students can apply for in connection with research stays abroad if their application provides a clear explanation on how the research stay will benefit their current project and QuSpin.

The purpose of this grant is to learn and transfer research methods or techniques relevant to the project and QuSpin as a whole. We emphasize that these research stays should create stronger professional relationships between the host, the PhD student and QuSpin, and that it should result in a joint publication.

The grant will typically cover travel and accommodation costs. Candidates can apply for financial support for up to three months for a research stay. After the completion of the research term the applicant is required to present findings and experiences during the annual research conference. In addition, a presentation will be required at the Center and on our webpage.

Our first two PhD students to receive this grant
The first two students to receive this grant were Lina Johnsen Kamra, who spent four months at RIKEN research institute in Tokyo, Japan during the autumn of 2022, and Bjørnulf Brekke, who is having a six month stay 2022-2023 at UCLA in Los Angeles, USA. They told Karen-Elisabeth about their experiences.



Lina's Journey to RIKEN, Tokyo

My motivation
The possibility for a research stay abroad was an important factor in my decision to do a PhD at QuSpin. It is a unique possibility to join a research group that would have been "out of my league" if I had been applying for PhD positions directly after my Master's.

The process from idea to action
I started planning to go for exchange already in my first PhD year and had valuable help from my supervisor at QuSpin, Professor Jacob Linder, in finding a host. But because of the pandemic I had to wait until my last year since Japan and RIKEN did not open up for foreigners until the summer of 2022. Getting a visa and a place to stay went very smoothly because of the very helpful and competent secretary Tokuyoshi-san who took care of everything for me.

I was staying with Prof. Naoto Nagaosa at RIKEN in Saitama, close to Tokyo. I also got close supervision by our collaborator Prof. Yukio Tanaka at Nagoya University. I was working on local and optical responses of the Majorana edge mode in a ferromagnetic insulator/unconventional superconductor hybrid on top of a topological insulator.

Experiencing a new research culture, collaboration, and supervision
The professors I was working with were amazing for their passion for physics. We often had discussions late in the evening, even lasting until after midnight. I enjoyed escaping the culture of going home at four that is so common in Norway, and really being able to focus on my research without people reminding me to take breaks. I shared an office with colleagues from the Nagaosa and Arita groups and enjoyed having lunch and coffee beaks with my office mates. Although I also got to know some of the experimentalists in the Tokura group, meeting new people and staying connected with the different groups at campus was a bit tough due to the Covid restrictions and many meetings still being online.

Experiences from a different country, society and social life
My friends in the office originated from China, Taiwan, South Korea, and a few from Japan, and some of the people had lived in the US before coming to RIKEN. It was therefore a quite multicultural environment, and everyone was fluent in English. I was surprised how similar the Japanese culture and way of behaving is to Norwegian culture, and I felt quite at home in Tokyo. The language was however a challenge outside Campus, so I had to learn how to read some Japanese to manage to read train stops, and shop in grocery stores.

Challenges and joys
The biggest challenge was the eight-hour time difference compared to Europe. This was a lot more challenging than I expected, because I would often go to bed before my husband living in Europe came home from work, so at times we would miss out on our daily chat. However, I really enjoyed working at RIKEN around so many motivated and excellent people, and to explore the city with its shrines and temples, towers, parks, interesting food, and hiking opportunities.

My advice to other PhD students
If you want to pursue a career in academia, a research stay abroad helps you develop in a way you can only do if you visit new places and talk to different people. You build a network that can help you get interesting opportunities in the future.

I would highly recommend taking the initiative early in your PhD. You will make up for the work it takes to plan and prepare by the opportunities that open up by going abroad!

Bjørnulf's Journey to UCLA, LA

My motivation
Towards the end of my Master's degree, I had to decide if I wanted to pursue a PhD abroad or stay at QuSpin in Trondheim. The possibility for a research stay abroad was an important factor in making my decision. For me, international experience is important from a scientific point of view as well as for maturity and life experience in general.

The process from idea to action
The pandemic prevented travelling during the first two years of my PhD. When society opened up, I discussed my wishes with my supervisor Professor Arne Brataas. His large international network provided several opportunities. After conferring with two of his former students, Sverre Gulbrandsen and Erlend Grytli Tveten, I decided to visit Professor Yaroslav Tserkovnyak at UCLA to study the topological properties of supercurrents. The visa application process was cumbersome, but good help from our center coordinator Karen-Elisabeth Sødahl just across the hallway and the opportunity to ventilate any frustrations in the lunchroom to other voluntary or involuntary QuSpinners eased the process.

Experiencing a new research culture, collaboration, and supervision
The UCLA campus has a very active feel to it. There are great facilities for sports and an evident pride of being a part of UCLA or being a so-called «bruin» flows through campus. Yaroslav's research group provides a different collaboration dynamic from QuSpin. There are two main reasons for that. Firstly, Yaroslav is very hands-on on each of his students' research projects. Also, sharing an office with graduate students within the group facilitated a lot of discussions both related and unrelated to our research. However, although the research group feels very close, the condensed matter section as a whole does not feel as connected as QuSpin.

Experiences from a different country, society and social life
Los Angeles feels very different from Trondheim. It is extremely diverse in terms of culture, background and wealth. The diversity gives LA a unique character yet serves as a peeking hole to cultures all over the world.

Challenges and joys
I would argue that a stay abroad at the PhD level is more challenging than an Erasmus exchange year. However, being more personally and academically mature has helped a lot towards making the stay enjoyable and successful. Doing a research project abroad has required academic independence beyond my experience at QuSpin so far.

Advice to other PhD students
If you are going for a research stay abroad, be proactive! Nothing will come for free, but there will be plenty of help and opportunities for anyone who reaches out.

I have been lucky to be part of a great beach volleyball community in Santa Monica. And I look forward to seeing them again the next time I am in Los Angeles.

Finally, where does your journey take you next?
"Thanks to the great support and encouragement from Prof. Nagaosa, this stay at RIKEN has opened new doors for pursuing an academic career," says Lina. "My plan is to apply for a grant that can finance a Postdoc position from 2024. Maybe a university on the East Coast of the United States will be my next address?"

"The vibrant physics community and the extraordinary people at UCLA have opened my eyes to the many career opportunities both within and outside of academia," says Bjørnulf. And he continues: "I have yet to decide for myself which direction to pursue. The many discussions with my friends and co-workers at UCLA and QuSpin will surely help me make the right choice."

QUANTUM SPINTRONICS 2022

Our Annual International Conference

The speakers at our conference (from left): Milena Grifoni, Alex Khajetoorians, Jeroen van den Brink, Tero Heikkilä, Kaveh Lahabi, Stuart Parkin, Andrii Schumak, Vira Shyta, Sol H. Jacobsen, Niladri Banerjee, Asle Sudbø, Manuel Bibes, Jean-Marc Triscone, Andrew Kent and Hendrik Bentmann.

Our researchers must gather with leading international professionals outside QuSpin. Targeted conferences spark inspiring dialogues around current challenges and findings and are the ideal breeding ground for a creative environment for focused peer discussions.

In 2022 we had the pleasure of inviting to a three-day conference from 13-15 June in Trondheim Spektrum, a place beautifully located on a peninsula surrounded by the river Nidelven and in walking distance from the hotel in the city center.

The fifteen speakers, representing both the theoretical and experimental areas, shared their perspectives and work with around sixty participants physically present at the conference center. The various talks on state-of-the-art research were very inspiring to us all. The size of this conference with its open and rather informal atmosphere invited to interaction on many levels.

It is important for QuSpin to facilitate a stage for presentations not only by senior researchers but to also give younger researchers in the early phase of their careers the opportunity to gain presentation training and get feedback and have discussions on their scientific work.

We also included poster sessions presenting work from our center and participants. This created a basis for many fruitful and enjoyable discussions among fellow researchers and has resulted in concrete collaborations between international researchers.

Our conferences are not all work and no play. We invited everyone to a guided boat trip on the river Nidelven.

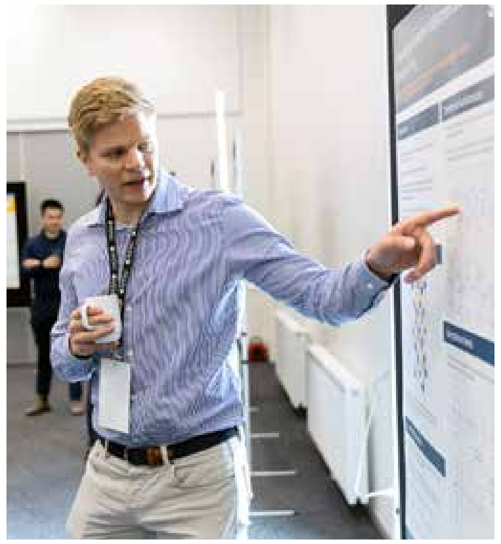
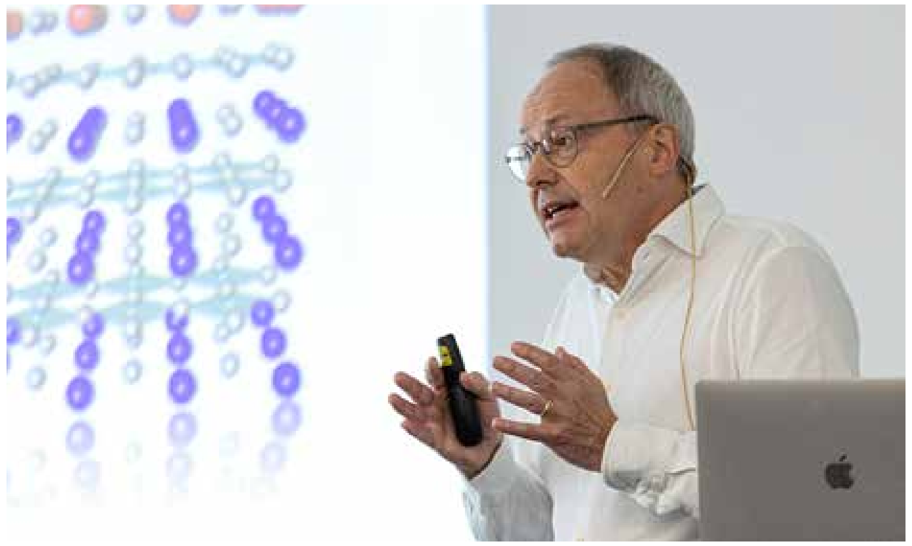
Our original plan was to go ashore on the island of Munkholmen which historically was the seat for a monastery and thereafter a fortress. In the last minute we had to change plans and were happy to welcome our participants to dinner at Trondheim's Grand Hotel Britannia, or the "White Swan" as the locals call it.

We look forward to opening up our next three-day scientific conference, in June 2024, to a larger audience.

QUANTUM SPINTRONICS 2022








QuSpin Posters

The posters presented by our Postdocs and PhD students at our international conference Quantum Spintronics 2022 gave an interesting overview of the ongoing projects at our Center.

A committee was given the task to award the best poster 2022 based on the following main criteria graded from 1-5 (highest): structure, technical quality, visual presentation, and clarity. It was a close race!

1D Spin Polarised Surfce States in Bi (112)
Anna Cecilie Åsland, Johannes Bakkelund, Even Thingstad, Håkon I. Røst, Simon Coill, Federico Mazzola, Jinbang Hu, Asle Sudbø, Justin W.Wells

2D hole gas Josephson junction
Jonas Lidal and Jeroen Danon

Complete magnetic control over the superconducting thermoelectric effect
J. A. Ouassou, C. Gonzáles-Ruano, D. Caso, F. G. Aliev & J. Linder

Curvature control of the superconducting proximity effect in diffusive ferromagnetic nanowires
Tancredi Salamone, Henning G. Hugdal, Morten Amundsen, and Sol H. Jacobsen

Epitaxial growth of Fe-Sn Kagome Lattice
Payel Chatterjee, Matthias Hartl, Longfei He, Simen Johnsrud, Stefanie S. Brinkman, Dennis Meier, Christoph Brüne

Going beyond the Chandrasekhar-Clogston limit in a flat-band superconductor
Atousa Ghanbari*, Eirik Erlandsen*, Asle Sudbø, Jacob Linder

Low-energy properties of Electrons and Holes in $CuFeS_2$
Bjørnulf Brekke, Roman Malyshev, Ingeborg-Helene Svenum, Sverre M. Selbach, Thomas Tybell, Christoph Brüne, Arne Brataas

Terahertz spin current pulses from an off-resonant antiferromagnet
Chi Sun*, Hyunsoo Yang, Arne Brataas and Mansoor B. A. Jalil

Quasiclassical theory for antiferromagnetic and superconducting structures
Eirik Holm Fyhn*, Arne Brataas, Alireza Qaiumzadeh and Jacob Linder

Magnon drag in a metal-insulating antiferromagnet bilayer
Eirik Erlandsen and Asle Sudbø

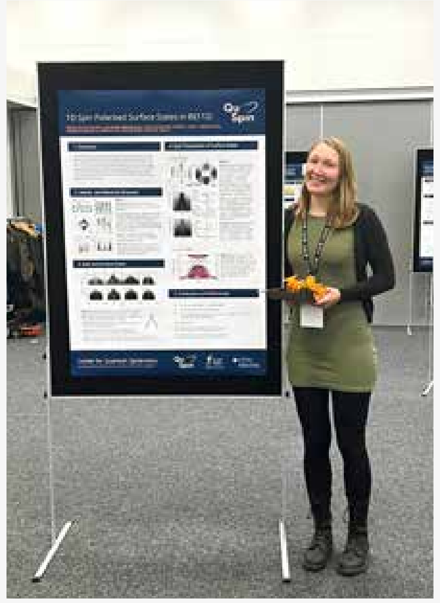
Magnon-mediated superconductivity in a Luttinger liquid
Niels Henrik Aase and Asle Sudbø

MBE Growth of the Antiferromagnetic Semiconductor Chalcopyrite $CuFeS_2$
Matthias Hartl, Stefanie S. Brinkman, Payel Chatterjee, Longfei He, Simen Johnsrud, Christoph Brüne

MBE growth of noncollinear antiferromagnetic Mn3Sn
Longfei He, Payel Chatterjee, Matthias Hartl, Dennis Meier, Christoph Brüne

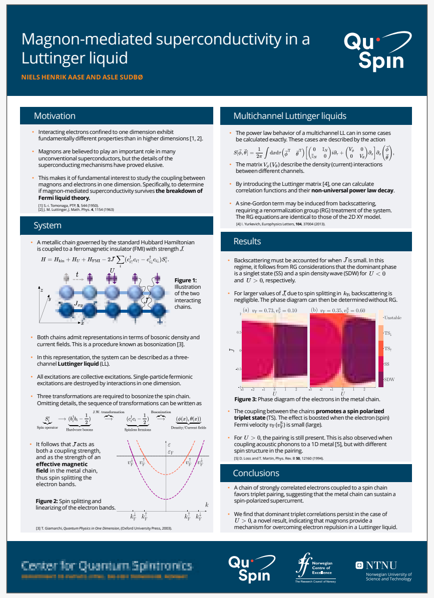
Quantum fluctuations in the order parameter of quantum skyrmion crystals
Kristian Mæland and Asle Sudbø

Spin transport in easy-plane antiferromagnetic insulators
Verena Brehm and Alireza Qaiumzadeh



PhD student Anna Cecilie Åsland is receiving the award for the "Best Poster 2022".

1D Spin Polarised Surfce States in Bi(112)
Anna Cecilie Åsland, Johannes Bakkelund, Even Thingstad, Håkon I.Røst, Simon Coill, Federico Mazzola, Jinbang Hu, Asle Sudbø, Justin W.Wells



PhD student Niels Henrik Aase received the award for the "Best Poster" at the summer school Physics by the Lake in Stirling, Scotland.

Talks and Presentations

One of our key goals is to make physics in general, and the research at our Center in particular, attractive to other researchers and students. And by sharing the work through accessible language and tangible examples, illustrating why our research is crucial and worth funding. This year our researchers were giving various talks and presenting posters, both locally and internationally.

FEBRUARY

Nordic virtual condensed matter seminar
Talk by Professor Linder, Jacob. Title: *Triplet Cooper pair supercurrent inducing a magnon spin-current.*

Talk by Professor Jacob Linder. Title: *Magnon spin-current induced by a triplet Cooper pair.*

MARCH

APS March Meeting 2022, online
Talk by PhD student Kristian Mæland. Title: *Electron-magnon coupling and quasiparticle lifetimes on the surface of a topological insulator.*

University of Oslo, Norway
Talk by Postdoc Jabir Ali Ouassou. Title: *Voltage-induced superconductivity in high magnetic fields.*

Norway - Japan Quantum Computing Webinar. Online
Talk by Professor Jeroen Danon. Title: *Quantum Computing Technology – Norway.*

TRR 80: From Electronic Correlations to Functionality Seminar, Augsburg, Germany
Talk by Professor Dennis Meier. Title: *Functional topological solitons in chiral and non-chiral materials.*

Realfagsdagene, NTNU, Trondheim, Norway
Talk by Professor Jacob Linder. Title: *Superconductors turn up to the heat.*

MAY

Novel Quantum Phases in Superconducting Heterostructures. 769. WE-Heraeus-Seminar, Bad Honnef, Germany
Talk by Professor Jacob Linder. Title: *Breaking the Clogston-Chandrasekhar limit via flat bands and giant anisotropy in antiferromagnetic Josephson junctions.*

Workshop on Emergent phenomena in low-dimensional ferroelectric structures, Berlin, Germany
Talk byProfessor Dennis Meier. Title: *The third dimension of ferroelectric domain walls.*

JUNE

IEEE-UFFC's FerroSchool, Lyon, France
Talk by Professor Dennis Meier. Title: *Improper ferroelectrics – domains, domain walls and emergent functional properties.*

JULY

UCSB Quantum Foundry, Santa Barbara, USA
Talk by PhD student Håkon Røst. Title: *Disentangling Rich Many-Body Physics with Modern Photoemission Techniques.*

AUGUST

Summer School "Physics by the Lake" i Stirling, Skottland
Poster by PhD student Niels Henrik Aase. Title: *Magnon-mediated superconductivity in a Luttinger liquid.*

University of Regensburg PhD Summer School on "Dynamics of Lower-Dimensional Systems", Nürnberg, Germany
3 hours of lectures by Professor Jeroen Danon. Title: *Solid-State Spin Qubits.*

CMD29 workshop on geometric design in spintronics, Manchester, England
Talk by Senior researcher Dr. Sol Jacobsen. Title: *Superconducting spintronics in curved geometries.*

SEPTEMBER

Nordic Quantum Connection Workshop, Helsinki, Finland
Talk by Professor Jeroen Danon. Title: *Solid-State Spin Qubits.*

CRIM2022 - Superconducting spintronics in low dimensions, London, UK
Talk by Professor Jacob Linder. Title: *Complete magnetic control over the superconducting thermoelectric effect.*

Materials Science and Engineering Congress (MSE 2022), Darmstadt, Germany
Talk by Professor Dennis Meier. Title: *The third dimension of ferroelectric domain walls*

International Workshop on Topological Structures (TOPO 2022), Mainz, Germany
Talk by Professor Dennis Meier. Title: *Nanoscale 3D imaging of ferroelectric domain wall networks*

Spin Qubit 5 Conference, Pontresina, Switzerland
Talk by Professor Jeroen Danon. Title: *Spin blockade and spin-orbit coupling.*

DPG Conference, Regensburg, Germany
Talk by Professor Dennis Meier. Title: *Functional ferroics*

OCTOBER

Linjeforeningen Delta, NTNU, Trondheim, Norway
Inspirational talk by Senior researcher Dr. Sol Jacobsen.

Korea-Nordic co-operation workshop on Quantum Materials, Stockholm, Sweden
Talk by Senior researcher Dr. Sol Jacobsen. Title: *The role of geometric design in superconducting spintronics.*

NOVEMBER

IIT Madras, India. Webinar on the physics of functional oxide material and devices.
Talk by Professor Dennis Meier. Title: *Improper ferroelectric domain walls for next-generation nanoelectronics.*

MRS Fall Meeting, Boston, USA.
Talk by Professor Dennis Meier. Title: *The third dimension of ferroelectric domain walls.*

Seminar at Ecole de Physique, Universite de Geneve, Switzerland.
Talk by Professor Asle Sudbø. Title: *Spin-fluctuations and unconventional superconductivity in heterostructures of magnetic insulators and gapless fermion systems.*

Universität Konstanz, Germany.
Invited talk by Professor Jacob Linder. Title: *Spin-polarized long-ranged superconductivity in antiferromagnets*

Department Colloquium, Universität Konstanz, Germany
Talk by Professor Jacob Linder. Title: *Long-ranged spin-polarized superconductivity in antiferromagnets.*

TNNN conference 2022, Horten, Norway
Poster and talk by PhD student Anna Cecilie Åsland. Title: *One-Dimensional Spin-Polarised Surface States on Bi(112) Compared to States on Other Vicinal Surfaces of Bi.*

AVS 68th International Symposium & Exhibition, Pittsburg, USA
Talk by Associate professor Hendrik Bentmann. Title: *Topological States in the van der Waals Magnet MnBi2Te4: from 3D to 2D.*

Superconducting spintronics 2022- International workshop on superconducting spintronics Online (Zoom)
Talk by Professor Jacob Linder. Title: *Superconducting spintronics: a review of its present state.*

Talk by PhD student Lina Johnsen Kamra. Title: *Spin-triplet superconductivity: Controllable enhancement and coupling to magnon spin currents.*

Glimpses from Our Center

Diversity leadership is about the strength we find in our differences and fostering that potential.

Diversity and different perspectives are essential factors in our approach of challenging questions in our Research Center. Each researcher and student who comes to the Center brings their unique personality and experience to the group dynamics, and we notice how this adds value to our work .

Our Center's researchers have their roots in ten different countries. They come from different walks of life, cultures, and ethnicities. They speak a variety of languages and are of diverse genders.

We spend time and resources on developing a prosocial and robust culture. We build arenas where people can meet, create, and interact. We also arranged cafés for younger female students to attract more of them to write their project or master theses at our Center.

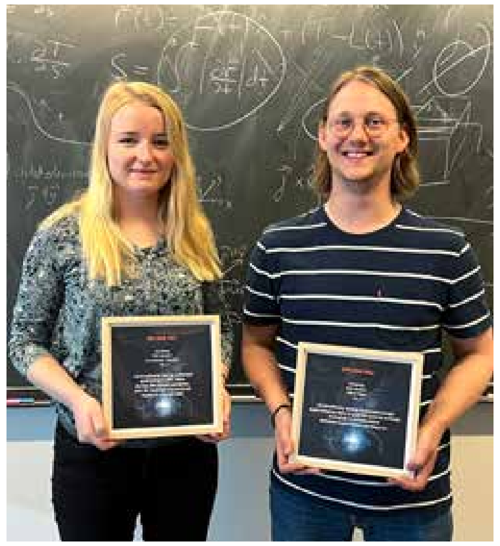
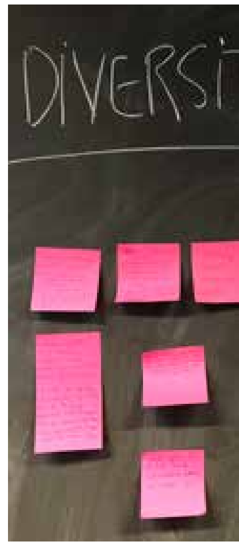
We used every opportunity for social gatherings, celebrating successful publications in the Physical Review Letter (PRL), Christmas and Easter holidays, as well as wishing good colleagues and friends all the best on their journey to the next phase in their careers.

We also had three different workshops through the year as part of our QuSpin Balance project 2021-2022. The workshops facilitated a platform for looking into various challenges and opportunities regarding gender balance, diversity and equality at our Center.

This year we re-installed handing out the annual QuSpin Diplomas. The diploma is meant to be a recognition of effort at the Center as to scientific or social contributions to our working culture.

We hope that everyone feels welcome and thrives in our research environment and we are very happy that initiatives for social interaction and fun being taken outside of QuSpin as well.

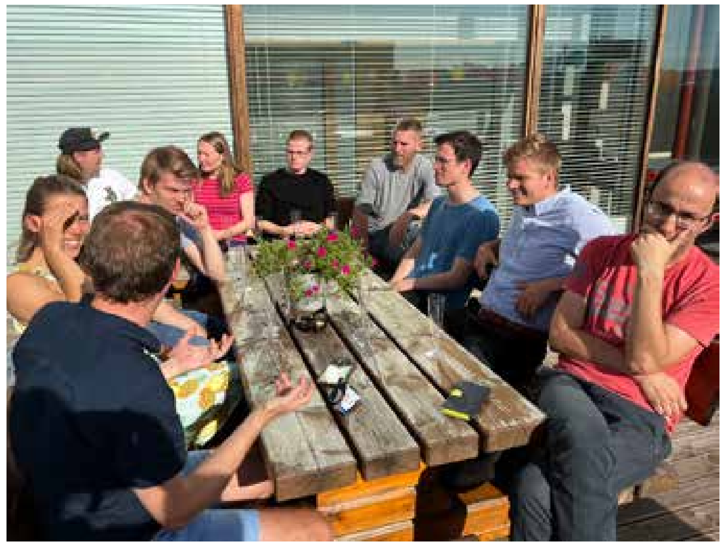
All in all, we are impressed with everyone for keeping up the spirit and for persisting in work and social interaction with their peers!










PhD Defenses and Completed Master Theses

We congratulate our PhD candidates who successfully completed their defenses and our Master's students who completed their theses. We wish them all the best in the next phase of their journey!

COMPLETED PHD'S

Erlandsen, Eirik. PhD Defense September 23rd, 2022. Title: *Magnon-mediated superconductivity and other collective phenomena in heterostructures of magnets and conductors.* Supervisor: Professor Asle Sudbø. Co-supervisor: Professor Jacob Linder.

Ghanbari, Atousa Birgani. PhD Defense March 4th, 2022. Title: *RKKY interaction and coexistence with magnetism in superconducting systems.* Supervisor: Professor Jacob Linder. Co-supervisor: Professor Asle Sudbø.

Ghini, Jonas Blomberg. PhD Defense June 17th, 2022. Title: *Transient heat transfer to confined superfluid helium.* Supervisor: Professor Asle Sudbø. Co-supervisors: Dr. Bernhard Auchmann and Dr. Bertrand Baudouy.

Janssønn, Andreas T.G. PhD Defense September 2nd, 2022. Title: *Cavity-mediated impact of superconductors on ferromagnetic insulators.* Supervisor: Senior researcher Sol H. Jacobsen. Co-supervisor: Professor Arne Brataas.

Røst, Håkon Ivarssønn. PhD Defense September 16th, 2022. Title: *Novel Approaches for Exploring Electron Interactions in Reduced Dimensions.* Supervisor: Professor Justin Wells. Co-supervisor: Dr. Simon Coill (UiO) and Dr. Lars Thomsen, Australian Synchroton.

Qvist, Jørgen Holme. PhD Defense August 26th, 2022. Title: *Effects of Hyperfine and Spin Orbit interaction in multiple-spin qubits.* Supervisor: Professor Jeroen Danon. Co-supervisor: Professor Asle Sudbø.

COMPLETED MASTER THESES

Austefjord, Johannes W. Title: *An antiferromagnetic and insulating leaky integrate-and-fire neuron and its application.* Supervisor: Senior researcher Alireza Qaiumzadeh.

Ballestad, Thorvald Molthe. Title: *Anomalous Thermoelectric Effect in Tilted Dirac and Weyl Semimetals.* Supervisor: Senior researcher Alireza Qaiumzadeh.

Benestad, Jacob Daniel. Title: *Electron-magnon coupling and magnon-induced superconductivity in hybrid structures of metals and magnets with non-collinear ground states.* Supervisor: Professor Asle Sudbø.

Breivik, Mariell. Title: *Simulating pure odd-frequency Josephson Junctions with conventional superconductors.* Supervisor: Senior researcher Sol H. Jacobsen.

Finnseth, Øyvind. Title: *Ferromagnetically mediated singlet-triplet qubit coupling.* Supervisor: Professor Jeroen Danon.

Flem, Ulrik Røssevold. Title: *Electron-magnon coupling with anisotropic ferromagnets.* Supervisor: Professor Asle Sudbø.

Fosstveit, Stein Kåre Lundeberg. Title: *Spin and Thermal Hall Effects in the Strongly Correlated Kane-Mele-Hubbard Model.* Supervisor: Senior Researcher Alireza Qaiumzadeh.

Giil, Hans Gløckner. Title: *Spin Accumulation and Effective Models for Odd-Frequency Superconductivity.* Supervisor: Professor Jacob Linder.

Haas, Max. Title: *Supercurrent 0-π oscillations induced by spin-orbit coupling.* Supervisor: Professor Jeroen Danon. Co-supervisor: Professor Dennis Meier.

Hodt, Erik Wegner. Title: *Quantum phase diagram and transient dynamics of the Rashba-Hubbard model.* Supervisor: Professor Jacob Linder.

Høye, Osmund. Title: *Study of a Triangular-Domain Topological Qubit Model with Edge disorder.* Supervisor: Professor Jeroen Danon.

Johnsrud, Simen. Title: *Molecular Beam Epitaxy Growth of the Kagome magnet system Fe-Sn.* Supervisor: Associate professor Christoph Brüne.

Samuelsen, Erik Sefland. Title: *Ultrafast magnon-phonon dynamics.* Supervisor: Senior researcher Alireza Qaiumzadeh.

Skarpeid, Alf Johan. Title: *Diffusive Curved Superconductor-Ferromagnet Proximity Systems in and out of Equilibrium.* Supervisor: Sol H. Jacobsen.

Tønseth, Even Aksnes. Title: *Antiferromagnetic Neuromorphic Computing.* Supervisor: Senior researcher Alireza Qaiumzadeh.

Uthayamoorthy, Viroshaan. Title: *Quantum Machine Learning for Variational Quantum Algorithms.* Supervisor: Professor Jeroen Danon.

Atousa Birigini Ghanbari and Jacob Linder.

Asle Sudbø and Jonas Blomberg Ghini.

Jørgen Holme Qvist and Jeroen Danon.

Sol H. Jacobsen and Andreas T.G. Janssønn.

Eirik Erlandsen and Asle Sudbø.

Simon Coill, Håkon Ivarssønn Røst and Justin Wells.

Honors and Grants

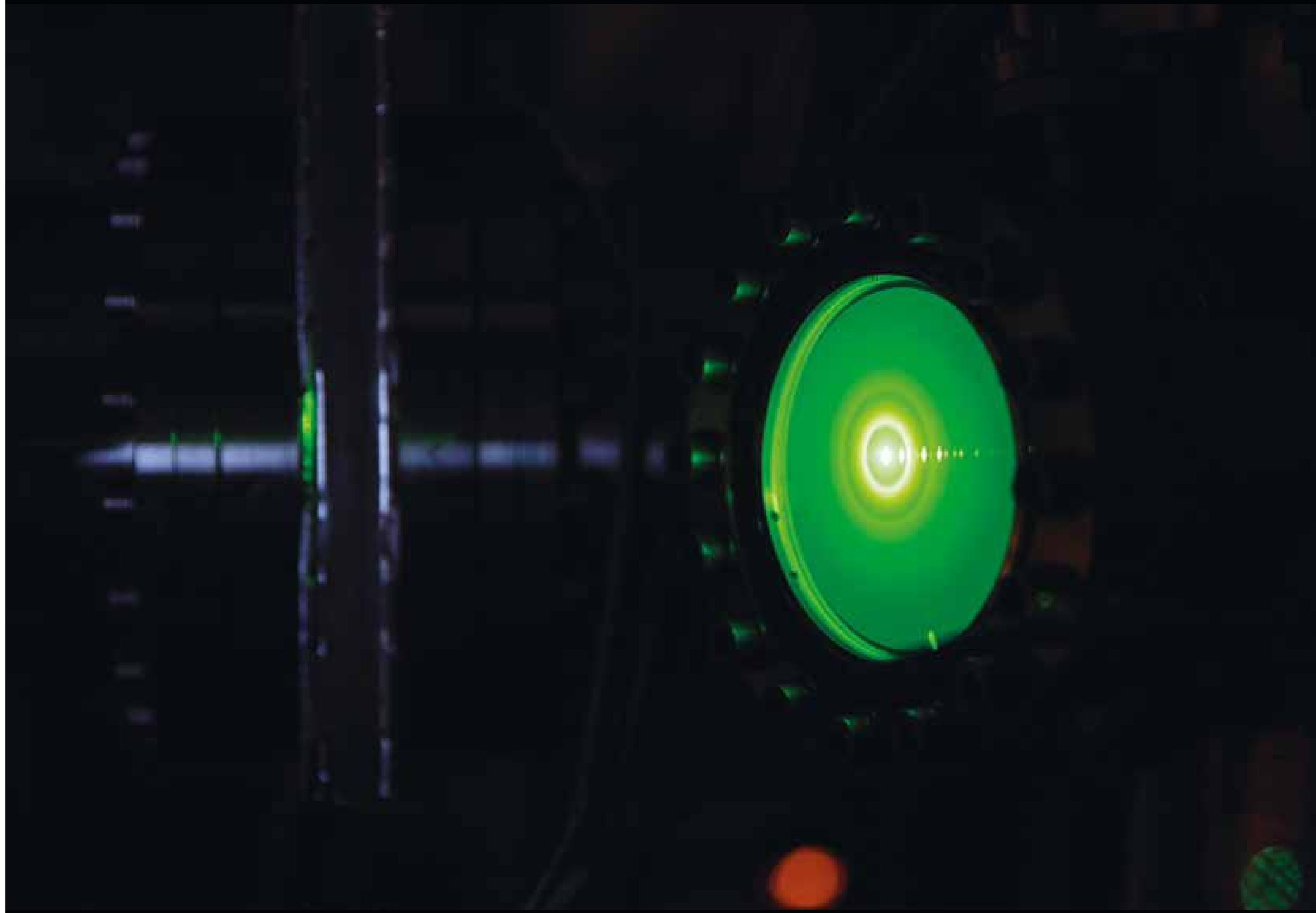
We had a great year with several honors and grants to our researchers. We highly appreciate the acknowledgment of our colleagues work, and the opportunities this represents for the further development of our center.

NORWEGIAN ACADEMY OF THE TECHNIAL SCIENCES (NTVA)

Professor Jacob Linder has been elected as member of the Norwegian Academy of the Technical Sciences (NTVA), Norway. The purpose of NTVA is to promote science, education, and development within the technical sciences and associated scientific fields. To become a member, the person should have a documented independent scientific contribution to the technical sciences or associated scientific fields, or have made an important contribution to the promotion of technology or technical sciences.

EUROPEAN MAGNETISM ASSOCIATION (EMA)

Professor Dennis Meier has been elected vice-president of the European Magnetism Association (EMA). The purpose of the European Magnetism Association is to promote the development of magnetism and magnetic materials in Europe, through rising the visibility and the impact of research on fundamental and applied magnetism. EMA acts as an umbrella organization for activities in magnetism in Europe, giving magnetism a strong voice in the concert of physical sciences.



MBE lab: Reflection high energy electron diffraction (RHEED). Electron coming hitting the fluorescent screen.

Highlights

MARCH

PhD Defense
Atousa Ghanbari Birgani

JUNE

PhD Defense
Jonas Blomberg Ghini

Quantum Spintronics 2022
International Conference

AUGUST

PhD Defense
Jørgen Holme Qvist

Hiring
Head of ARPES lab
Associate Professor
Hendrik Bentmann

SEPTEMBER

PhD Defense
Andreas T. G. Janssønn

PhD Defense
Håkon Ivarssønn Røst

PhD Defense
Eirik Erlandsen

NOVEMBER

NTVA
Member
Professor Jacob Linder

Ema
Vise-President
Professor Dennis Meier

DECEMBER

Final QuSpin Balanse
Workshop

QuSpin Collaboration
Workshop

Scientific Publications

We are privileged to have the work of our researchers published in journals such as Science, Physical Review Letters and Physical Review B. Our center has had fifty-five publications over the last year, and we look forward to continuing to add to our library of published research.

1. Shilei Ding, Zhongyu Liang, Dongwook Go, Chao Yun, Mingzhu Xue, Zhou Liu, Sven Becker, Wenyun Yang, Honglin Du, Changsheng Wang, Yingchang Yang, Gerhard Jakob, Mathias Kläui, Yuriy Mokrousov, and Jinbo Yang.
Observation of the Orbital Rashba-Edelstein Magnetoresistance. ***Physical Review Letters*** 128, 067201

2. Brataas, Arne.
Quantum scattering theory of spin transfer torque, spin pumping, and fluctuations. ***Physical Review B*** 106, 064402

3. Erlandsen; Eirik Erlandsen; Sudbø, Asle.
Magnon drag in a metal–insulating antiferromagnet bilayer. ***Physical Review B*** 105, 184434

4. Frostad, Therese; Skarsvåg, Hans Langva; Qaiumzadeh, Alireza; Brataas, Arne.
Spin-transfer-assisted parametric pumping of magnons in yttrium iron garnet. ***Physical Review B*** 106, 024423

5. Fyhn, Eirik Holm; Linder, Jacob.
Spin-orbit pumping. ***Physical Review B*** 105, L020409

6. Ghanbari, Atousa Erlandsen, Eirik; Sudbø, Asle; Linder, Jacob.
Going beyond the Chandrasekhar-Clogston limit in a flatband superconductor. ***Physical Review B*** 105, L060501

7. Haugen, Håvard Homleid; Sudbø, Asle.
Zero temperature superconductor–edge metal–insulator transition in two-dimensional bosonic systems.
Physical Review B 106, 064504

8. Linder, Jacob; Amundsen, Morten.
Quasiclassical boundary conditions for spin-orbit coupled interfaces with spin-charge conversion. ***Physical Review B*** 105, 064506

9. Mæland, Kristian; Sudbø, Asle.
Quantum fluctuations in the order parameter of quantum skyrmion crystals. ***Physical Review B*** 105, 224416

10. Ouassou, Jabir Ali; González-Ruano, César; Caso, Diego; Aliev, Farkhad G.; Linder, Jacob.
Complete magnetic control over the superconducting thermoelectric effect. ***Physical Review B*** 106, 094514

11. Qvist, Jørgen Holme; Danon, Jeroen.
Anisotropic g -tensors in hole quantum dots: Role of transverse confinement direction. ***Physical Review B*** 105, 075303

12. Qvist, Jørgen Holme; Danon, Jeroen.
Probing details of spin-orbit coupling through Pauli spin blockade. ***Physical Review B*** 106, 235312

13. Salamone, Tancredi; Hugdal; Henning G.; Amundsen, Morten; Jacobsen, Sol H.
Curvature control of the superconducting proximity effect in diffusive ferromagnetic nanowires.
Physical Review B 105, 134511

14. Sun, Chi; Yang, Hyunsoo; Jalil, Mansoor B. A.
Enhanced subterahertz spin-current transients via modulation of cross-sublattice daming in unaxial antiferromagnets.
Physical Review B 105 (10)

15. Mæland, Kristian; Sudbø, Asle.
Quantum topological phase transitions in skyrmion crystals. ***Physical Review Research*** 4, L032025

16. Sun, Chi; Yang, Hyunsoo; Brataas, Arne; Jalil, Mansoor B. A.
Terahertz Spin-Current Pulses from an Off-Resonant Antiferromagnet. ***Physical Review Applied*** 17, 034028

17. Wu, Rui; Ross, Andrew; Ding, Shilei; Peng,Yuxuan; He, Fangge ; Ren, Yi; Romain Lebrun, Romain; Wu,Yoing; Wang, Zhen; Yang, Jinbo; Brataas, Arne; Kläui, Mathias.
Magnetotransport Study of van der Waals CrPS4/(Pt, Pd) Heterostructures: Spin-Flop Transition and Room-Tempearture Anomalous Hall Effect. ***Physical Review Applied*** 17, 064038

18. Yan, H.Y.; Cao, Yunshan; Kamra, Akashdeep, Duine, Rembert A.; Yan,Peng.
Quantum magnonics: When magnon spintronics meets quantum information science. ***Physics Report*** 965

19. Shiranzaei, Mahroo; Troncoso, Roberto; Fransson, Jonas; Brataas, Arne; Qaiumzadeh, Alireza.
Thermal squeezing and nonlinear spectral shift of magnons in antiferromagnetic insulators. ***New Journal of Physics 2022*** 24, 103009

20. Franziska Martin, Kyujoon Lee, Maurice Schmitt, Anna Liedtke, Aga Shahee, Haakon Thømt Simensen, Tanja Scholz, Tom G. Saunderson, Dongwook Go, Martin Gradhand, Yuriy Mokrousov, Thibaud Denneulin, András Kovács, Bettina Lotsch, Arne Brataas & Mathias Kläui.
Strong bulk spin–orbit torques quantified in the van der Waals ferromagnet Fe3GeTe2. ***Materials Research Letters*** *11, 84*

21. Maurice Schmitt, Thibaud Denneulin, András Kovács, Tom G. Saunderson, Philipp Rüßmann, Aga Shahee, Tanja Scholz, Amir H. Tavabi, Martin Gradhand, Phivos Mavropoulos, Bettina V. Lotsch, Rafal E. Dunin-Borkowski, Yuriy Mokrousov, Stefan Blügel & Mathias Kläui.
Skyrmionic spin structures in layered Fe5GeTe2 up to room temperature. ***Communications Physics 5***: 254

22. Rui Wu, Andrew Ross, Shilei Ding, Yuxuan Peng, Fangge He, Yi Ren, Romain Lebrun, Yong Wu, Zhen Wang, Jinbo Yang, Arne Brataas, & Mathias Kläui.
Magnetotransport Study of van der Waals CrPS4/(Pt, Pd) Heterostructures: Spin-Flop Transition and Room-Temperature Anomalous Hall Effect. ***Physical Review Applied 17***, 064038

23. Shubhankar Das, A. Ross, X. X. Ma, S. Becker, C. Schmitt, F. van Duijn, E. F. Galindez-Ruales, F. Fuhrmann, M.-A. Syskaki, U. Ebels, V. Baltz, A.-L. Barra, H. Y. Chen, G. Jakob, S. X. Cao, J. Sinova, O. Gomonay, R. Lebrun & M. Kläui.
Anisotropic long-range spin transport in canted antiferromagnetic orthoferrite YFeO3. ***Nature Communications 13***: 6140

24. Stepanova, Mariia; Masell, Jan; Lysne, Erik; Schoenherr, Peggy; Köhler, Laura; Paulsen, Michael; Qaiumzadeh, Alireza; Kanazawa, Naoya; Rosch, Achim; Tokura, Yoshinori; Brataas, Arne; Garst, Markus; Meier, Dennis.
Detection of Topological Spin Textures via Nonlinear Magnetic Responses. ***Nano Letters*** 2022, 22, 1, 14–21

Facts

As of 2022.12.31.

9
PROF/ASSOC.PROF

2
SENIOR RESEARCHERS

4
POSTDOCS

22
PHD STUDENTS

16
MASTER STUDENTS

1
ADMINISTRATOR

10
DIFFERENT NATIONALITIES

19
VISITING RESEARCHERS

24
PUBLICATIONS

* Note: In addition we have a 25 % Finance Officer position, Head Engineer from the Department of Physics/NTNU, two Co-Principal Investigators in 17% and 20% positions, and one Prof. II position.

Funding

FUNDING 2022 (NOK)

The Research Council of Norway, Center of Excellence	6 196 000
Norwegian University of Science and Technology	15 813 000
SUM	**22 009 000**
The Research Council of Norway (Center of Excellence)	9 792 000
International Funding	1 259 000
Other Public	200 000
SUM	**11 251 000**
TOTAL FUNDING	**33 260 000**

People Overview

Colleagues who left QuSpin before 2022.12.31 are marked with an *

QUSPIN LEADER GROUP

Center Director Professor/ Principal Investigator
Arne Brataas

Professor/Principal Investigator
Asle Sudbø

Professor/Principal Investigator
Jacob Linder

Center Coordinator
Karen-Elisabeth Sødahl

ASSOCIATED MEMBERS

Associate Professor
Christoph Brüne

Associate Professor
Jeroen Danon

Associate Professor
John Ove Fjærestad

Professor (Onsager Fellow)
Dennis Gerhard Meier

Professor/Head of Department of Physics
Erik Wahlström

Associate Professor
Hendrik Bentmann

SENIOR RESEARCHERS

Sol H. Jacobsen

Alireza Qaiumzadeh

PROFESSOR II

Professor
Justin Wells

POSTDOCS


Marion Barbeau*


Jinbang Hu


Henning Goa Hugdal


Jabir Ali Ouassou


Chi Sun

PHD STUDENTS


Markus Altthaler*


Dag-Vidar Krogstad Bauer*


Atousa Ghanbari Birgani*


Verena Brehm


Bjørnulf Brekke


Payel Chatterjee


Eirik Erlandsen*


Vemund Falch


Eirik Holm Fyhn


Therese Frostad


Matthias Hartl


Håvard Homleid Haugen


Travis Gustavson


Erik Hodt


Jacob Daniel Benestad


Hans Glöckner Giil


Stefanie Brinkmann


Niels Henrik Aase

PHD STUDENTS

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Andreas T. G. Janssønn*

Kristian Mæland

Lina Johnsen Kamra

Christian Svingen Johnsen

Jonas Lidal

Frode Sneve Strand

Anna Cecilie Åsland

Jørgen Holme Qvist*

Håkon Ivarssøn Røst*

Tancredi Salamone

MASTER STUDENTS

Abnar, Sara
Aunsmo, Sigrid
Beronio, Ellaine R.A.
Ekrheim, Stine
Falch, Håvard
Høydalsvik, Eirik Jaccheri
Kløgetvedt, Jostein N.
Kristoffersen, Anne Louise
Lind-Olsen, Jesper
Lundemo, Sondre Duna
Lyngaas, Jens A.
Roheim, Marthe Elise Fiskerstrand
Rørbakken, Øyvind B.
Skjærpe, Magnus Skjærpe
Tietjen, Finja
Tjernshaugen, Johanne Bratland

CO-PRINCIPAL INVESTIGATORS

Professor
Rembert Duine, University of Utrecht
The Netherlands

Professor
Mathias Kläui, University of Mainz
Germany

HEAD ENGINEER

Senior Engineer*
Rajesh Kumar Chellappan
Department of Physics, NTNU

THE QUSPIN BOARD

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University of Hamburg, Germany

Professor
Jason Robinson
University of Cambridge, United Kingdom

QuSpin Alumni

Here are the members of our QuSpin Alumni. They are previous researchers at our Center, who are now in new positions within academia, research institutions, and industry.

Dr. Simon Coill
Associate professor II 2018-2020
Next position: Postdoc at the Department of Physics, University of Oslo, Norway

Akashdeep Kamra
Researcher 2021
Next position: Junior Group Leader at the IFIMAC - Condensed Matter Physics Center, Universidad Autónoma de Madrid, Madrid, Spain

Dr. Niklas Rohling
Researcher 2019
Next position: PostDoc at Universität Konstanz, Konstanz, Germany

Dr. Marion Barbeau
PostDoc 2019-2022
Next position: Researcher in Photonics for Health, Imec, Eindhoven, The Netherlands

Dr. Vasil Saroka
PostDoc 2018-2021
Next position: Tor Vergata University of Rome, Italy

Dr. Mariia Stepanova
PostDoc 2019-2021
Next position: Materials Engineer and Data Analyst, Norsk Titanum AS, Hønefoss, Norway

Dr. Junhui Zheng
PostDoc 2020
Next position: Associated Professor at the Institute of Modern Physics, Northwest University, Xi'an, China

Dr. Rui Wu
PostDoc 2020
Next position: Associate professor in colleague of physics at University of Electronic Science and Technology of China (UESTC)

Dr. Roberto Troncoso
PostDoc 2020
Next position: Associate professor at the Faculty of Engineering of University Adolfo Ibánez, Santiago, Chile

Dr. Rajesh Kumar Chellappan
PostDoc 2019
Next position: Technical Reviewer/Assessor, DNV Product Assurance AS, Høvik, Norway

Dr. Alex Schenk
PostDoc 2019
Next position: La Trobe University, Melbourne, Australia

Dr. Maximillian Kessel
PostDoc 2019
Next position: Scientist at Fraunhofer-Institute for Applied Solid State Physics in Freiburg, Germany

Dr. Xiansi Wang
PostDoc 2018-2020
Next position: Professor at Hunan University, Changsa, China

Dr. Jonas Blomberg Ghini
PhD 2022
Next position: Power engineering consultant at Multiconsult, Trondheim, Norway

Dr. Håkon Ivarssønn Røst
PhD 2022
Next position: Postdoctoral Fellow at the Department of Physics and Technology, University of Bergen, Norway

Dr. Jørgen Holme Qvist
PhD 2022
Next position: TBA

Dr. Eirik Erlandsen
PhD 2022
Next position: Data Analyst at the Norwegian Bank (DnB), Oslo, Norway

Dr. Andreas T. G. Janssønn
PhD 2022
Next position: TBA

Dr. Atousa Ghanbari Birgani
PhD 2022
Next position: TBA

Dr. Markus Altthaler
PhD 2022
Next position: TBA

Dr. Martin Fonnum Jakobsen
PhD 2021
Next position: Researcher at the Norwegian Defence Research Establishment (FFI), Oslo, Norway

Dr. Even Thingstad
PhD 2021
Next position: Postdoctoral Fellow at Universität Basel, Switzerland

Dr. Fredrik Nicolai Krohg
PhD 2021
Next position: Security Analyst at Orange Cyberdefense, Norway

Dr. Erik Nikolai Lysne
PhD 2021
Next position: Fullstack Developer at Fink, Oslo, Norway

Dr. Haakon Krogstad
PhD 2021
Next position: Consultant at McKinsey, Oslo, Norway

Dr. Sverre Aamodt Gulbrandsen
PhD 2022
Next position: Researcher at Optonor AS, Trondheim, Norway

Dr. Arnau Sala
PhD 2020
Next position: PostDoc at Interuniversity Microelectronics Centre (IMEC), Leuven, Belgium

Dr. Morten Amundsen
PhD 2020
Next position: Postdoctoral Fellow at NORDITA, Stockholm, Sweden

Dr. Øyvind Johansen
PhD 2019
Next position: Service Consultant at Matrix Technology AG, Munich, Germany

Dr. Eirik Løhaugen Fjærbu
PhD 2019
Next position: Data Scientist at Deepinsight AS, Oslo, Norway

Dr. Vetle Kjære Risinggård
PhD 2019
Next position: Researcher at Norwegian Research Centre (NORCE), Kr.sand, Norway

Dr. Camilla Espedal
PhD 2013-2017
Next position: Research Scientist at SINTEF Energy Research, Trondheim, Norway

ANNUAL REPORT PUBLICATION DETAILS

Published by:
Center for Quantum Spintronics (QuSpin)

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