WACQT May review meeting 2024 - researcher presentations

Time	Person	Position	Pillar	University	Title	Abstract
Tuesday 14th May						
15:35-15:50	**Nassim Mahammedi**	Postdoc	Quantum sensing, metrology and Control	Stockholm univ.	SiC color centers engineering via Laser writing for quantum sensing and quantum communication	Quantum technologies (including quantum computing, communication and sensing) often require solid-state single quantum emitters that could be used as qubit supports or single-photon emitters. Color centers are crystal defects that present particular light absorption and/or emission properties which could be exploited in this aim. In the last three decades, color centers in materials like diamond and silicon carbide have been largely explored and exploited for various quantum applications. Silicon carbide (SiC) is a well known technology-friendly semiconductor that has been widely used in power electronics and has mature commercially-available technology. More recently, the multiple defects in SiC, including single silicon vacancy VSi and Nitrogen vacancy centers (NV centers) exhibited promising bright single-photon sources, qubit supports, and nanoscale sensors. In this work, we use the state-of-the-art home-built femtosecond laser writing system to create NV and single Si centers that could enable single-photon emission in the 4H-SiC platform.
15:50 - 16:05	**Hanna Linn**	Ph D student	Quantum computing theory	Chalmers	Resource analysis of quantum algorithms for coarse-grained protein folding models	Protein folding processes are a vital aspect of molecular biology that is hard to simulate with conventional computers. Quantum algorithms have been proven superior for certain problems and may help tackle this complex life science challenge. We analyze the resource requirements for simulating simplified yet computationally challenging protein folding models on a quantum computer, assessing the feasibility of these existing approaches in the current and near-future technological landscape. We calculate the minimum number of qubits, interactions, and two-qubit gates necessary to build a heuristic quantum algorithm with the specific information of a folding problem. We conclude that the number of qubits required falls within current technological capabilities. However, the limiting factor is the high number of interactions in the quantum algorithm, resulting in a quantum gate count unavailable today.
Wednesday 15th May						
09:00-09:15	**Simon Sundelin**	Ph D student	Quantum computing experiment	Chalmers	Quantum refrigeration powered by noise in a superconducting circuit	While dephasing noise frequently presents obstacles for quantum devices, it can become an asset in the context of a Brownian-type quantum refrigerator. Here we demonstrate a novel quantum thermal machine that leverages noise-assisted quantum transport to fuel a cooling engine in steady state. The device exploits symmetry-selective couplings between a superconducting artificial molecule and two microwave waveguides. These waveguides act as thermal reservoirs of different temperatures, which we regulate by employing synthesized thermal fields. We inject dephasing noise through a third channel that is longitudinally coupled to an artificial atom of the molecule. By varying the relative temperatures of the reservoirs and measuring heat currents with a resolution below 1 aW, we demonstrate that the device can be operated as a quantum heat engine, thermal accelerator and refrigerator. Our findings open new avenues for investigating quantum thermodynamics using superconducting quantum machines coupled to thermal microwave waveguides.
09:15-09:30	**Cameron Calcluth**	Ph D student	Quantum computing theory	Chalmers	Understanding quantum advantage in continuous variable quantum computing	Quantum advantage refers to the ability of quantum computers to solve certain problems exponentially faster than classical computers. For qubit-based quantum computers there exist many results on quantifying the ability of certain components to achieve quantum advantage. However, for continuous-variable quantum computers much less is known. To investigate this, we first developed a method to simulate a restricted class of continuous-variable computations to understand when these types of quantum computers are unable to outperform classical computers. Using this result, we provide the first sufficient condition to achieve quantum advantage using continuous variable quantum computing.
11:25-11:40	**Daniel Spegel-Lexne**	Ph D student	Quantum communication	Linköping univ	Fast generation, switching and sorting of transverse spatial photonic quantum states in few-mode optical fibers for quantum communication	Optical fibers have been successfully used to support many quantum communication protocols over many years. One important degree-of-freedom used in quantum communication and more general quantum information processing is the transverse spatial information of single-photons, notably orbital angular momentum (OAM) states of light. Unfortunately, standard telecommunication fibers do not support transverse spatial information. By using next-generation telecommunication few-mode optical fibers, these states can nevertheless be reliably propagated. In order to have a complete quantum communication platform based on transverse spatial encoding, the generation and switching of these states needs to be done at fast speed and this has been proven a challenge with bulk optics components (q-plates, spatial light modulators etc.). In our work, we show fast generation, switching and sorting of OAM states using photonic lanterns and few-mode-fibers. We also present a few-mode fiber platform where the fundamental wave-particle duality of OAM-encoded photons is demonstrated.
11:40-11:55	**William Stenlund**	Ph D student	Quantum sensing, metrology and Control	Linköping univ	Finding and Analyzing Defects in Semiconductors	Quantum technologies like single photon emitters and qubits can be enabled by point defects in semiconductors, with the NV-center in diamond being the most prominent example. There are many different semiconductors, each hosting massive amounts of defects, and to find the interesting ones a high-throughput screening workflow is employed. Analyzing the symmetry properties of the point defect orbitals provides information on the selection rules determining the polarization of absorbed and emitted light, helps to better understand features of the electronic structure such as degeneracies, and in general help understand and explain the physics of defects. We have developed an automated code to perform symmetry analysis of point defect orbitals obtained by plane-wave density functional theory simulations. One new defect found by our workflow is the Na substitutional in diamond. The calculations indicate the defect is a bright emitter in the near-infrared range, and depending on the charge state is a spin-1 or spin-3/2 system.
13:05-13:20	**Janka Biznarova**	Ph D student	Quantum computing experiment	Chalmers	Mitigation of interfacial dielectric loss in aluminum-on-silicon superconducting qubits	We demonstrate aluminum-on-silicon planar transmon qubits with time-averaged T_1 energy relaxation times of up to 270 µs, corresponding to Q = 5 million, and a highest observed value of 501 µs. Through materials analysis techniques and numerical simulations we investigate the dominant source of energy loss, and devise and demonstrate a strategy towards its mitigation. Growing aluminum films thicker than 300~nm reduces the presence of oxide, a known host of defects, near the substrate-metal interface, as confirmed by time-of-flight secondary ion mass spectrometry. A loss analysis of coplanar-waveguide resonators shows that this results in a reduction of dielectric loss due to two-level system defects. The correlation between the enhanced performance of our devices and the film thickness is due to the tendency of aluminum to grow in columnar structures of parallel grain boundaries: transmission electron microscopy shows larger grains in the thicker film, and consequently fewer grain boundaries containing oxide near the substrate-metal interface.
13:20-13:35	**Johan Kolvik**	Ph D student	Quantum communication	Chalmers	Release-free optomechanical crystals for low noise microwave-optics transduction	Superconducting microwave processors are among the leading quantum platforms. They benefit from long coherence times and fast interactions between Josephson junction-based qubits. However, they are limited in terms of long-range connectivity - an area where optical technology excels. We intend to harness the strengths of both optics and microwaves by developing transducers capable of quantum conversion between microwave and optical domains. Development of silicon-based piezo-optomechanical transducers has recently seen several orders of magnitude increase in efficiency, but still suffers from optical absorption induced noise. In this talk, we present our efforts on release-free optomechanical crystals to break the noise-efficiency trade-off in these devices.

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Thursday 16th May						
10:40-11:10	**Eleni Diamanti**	Professor, SAB	Quantum communication	CNRS and Sorbonne University	Secure communications in quantum networks	Quantum technologies have the potential to improve in an unprecedented way the security and efficiency of communications in network infrastructures. We discuss the current landscape in quantum communication and cryptography, and focus in particular on recent photonic implementations, using encoding in discrete or continuous properties of light, of central quantum network protocols, enabling secret key distribution, coin flipping with limited bias and verification of multiparty entanglement, with security guarantees impossible to achieve with only classical resources. We also describe current challenges in this field and our efforts towards the miniaturization of the developed photonic systems, their integration into telecommunication network infrastructures, including with satellite links, as well as the practical demonstration of novel protocols featuring a quantum advantage for a wide range of tasks. These advances enrich the resources and applications of the emerging quantum networks that will play a central role in the context of future global-scale quantum-safe communications.
11:10-11:40	**Steven Girvin**	Professor, SAB	Quantum computing theory	Yale University	Introduction to Dual-Rail Cavity Qubits	Dual-Rail qubits were originally proposed for optical quantum computation and communication, and the logical states are represented by a single photon which can be in one of two different modes. This talk will discuss recent experimental and theoretical progress extending this concept to a single microwave photon shared between two microwave cavities. Single-qubit gates require only simple beam-splitter operations between the two cavities and can now be performed with very high fidelity. Novel two-qubit entangling gates are also being developed. The most common error, loss of the photon, causes a leakage out of the logical code space, but this otherwise dangerous fault can be efficiently converted to an erasure, heralded by a change in the parity of the total photon number. Recent work by Shruti Puri and Jeff Thompson on Rydberg arrays has shown that erasure errors are efficiently corrected by concatenation of the error-detection code of the dual-rail qubit into a higher-level error correction code such as the surface code. The fact that erasure errors have heralded locations reduces their entropy and effectively doubles the distance of the higher-level code leading to very efficient error correction.
11:40-12:10	**Witlef Wieczorek**	Professor	Quantum sensing, metrology and Control	Chalmers	Towards quantum experiments with micrometer-sized levitated superconducting particles	Quantum states of massive objects have fascinated since the inception of quantum mechanics. Nowadays molecules of thousands of atoms and mechanical resonators weighing picograms to micrograms can be brought into quantum states. This capability enables tests of the validity of quantum mechanics and provides new avenues for quantum sensing technologies. To explore and utilize the quantum behavior of a massive object requires exceptional isolation from its environment combined with precise control over its quantum state. I will present our experiments that target achieving quantum control over the motion of objects with masses larger than 10^12 atomic mass units. These experiments are based on magnetically levitating a superconducting microparticle in cryogenic vacuum at millikelvin temperatures.
13:10-13:40	**Stefan Filipp**	Professor, Board	Quantum computing experiment	TU Munich	Tunable-coupler mediated interactions between two and more superconducting qubits	Superconducting qubit devices have recently demonstrated high-fidelity operations, high coherence times and improved scalability, making them a leading platform for quantum computing. Still, to render today's quantum processors practically useful, both the coherence time of qubits and the generation of entanglement needs to be enhanced further. To reach these goals we have optimised the fabrication processes to build resonators with quality factors of almost 10 million and qubit with coherence times exceeding 500 microseconds. Moreover, we have implemented tunable couplers to mediate interactions between two or more qubits. We compare adiabatic coupler-activated controlled-phase gates on two qubits with various pulse shapes and parameterisations. Using closed-loop optimal control schemes we reach gate fidelities of up to 99.9%. Furthermore, by parametrically driving the tunable couplers simultaneously we demonstrate the coherent transfer of excitations between distant qubits on a six-qubit ring. Based on this method we implement a multi-qubit gate to efficiently prepare multi-qubit GHZ states in a single step.
13:40-13:55	**Anuj Aggarwal**	Ph D student	Quantum computing experiment	Chalmers	Mitigating transients of flux pulses in a quantum processor	Flux pulses (baseband) are used in quantum processors for controlling flux-tunable elements such as tunable qubits and couplers. While the shape of a flux pulse is set at room temperature, due to components like bias-tee, cables, attenuators inside the cryostat, the flux pulse that reaches the quantum processor suffers from distortion and transient decay. We show how to characterize the transient affecting the flux pulse that controls the coupler in a 2-qubit processor. We further demonstrate a mitigation technique in which sending the correct phases of the flux pulse removes the transients, and show that overestimating the time constant of the transient still suppresses the distortions.
13.55-14:10	**Marcus Lindén**	Ph D student	Quantum sensing, metrology and Control	Lund univ. /Rise	Laser frequency stabilization beyond the Brownian noise limit	Ultra precise frequency stabilized lasers are core elements in modern metrology. They are used as oscillators in optical atomic clocks and are integral to interferometer-based tests of fundamental physics, such as gravity wave detectors. The most common scheme for frequency stabilizing a laser involves locking the frequency of the laser to a stable cavity resonance frequency. Typically, the cavity consists of two mirrors separated by a distance L which the resonance frequency depends on. In this scheme, any variation in cavity length ΔL will translate to a proportional variation in laser frequency Δν, which inherently increases the linewidth of the laser. This effect can be reduced by minimizing the relative length change, ΔL/L. In current state of the art laser stabilization, ΔL variations are attributed to Brownian motion in the atoms forming the mirrors and increasing L beyond a few tens of centimeters has proven to be difficult. By inserting a material with a low group velocity, a short cavity can, to the light, appear as if it was orders of magnitude longer. This has the effect of decreasing the frequency noise level, due to the Brownian motion, by the velocity reduction factor. In materials doped with rare earth ions such as Europium, a velocity reduction as large as 10^5 times can be achieved.
14:10-14:25	**Piotr Mironowicz**	Postdoc	Quantum communication	Stockholm univ.	More than one bit quantum randomness certification and expansion	One of the striking properties of quantum mechanics is the occurrence of the Bell type non-locality. They are a fundamental feature of the theory that allows two parties that share an entangled quantum system to observe correlations stronger than possible in classical physics. In addition to their theoretical significance, non-local correlations have practical applications, such as device-independent randomness generation, providing private unpredictable numbers even when they are obtained using devices delivered by an untrusted vendor. Thus, determining the quantity of certifiable randomness that can be produced using a specific set of non-local correlations is of significant interest. First, we present an experimental realization of recent Bell-type operators designed to provide private random numbers that are secure against adversaries with quantum resources. We use semi-definite programming to provide lower bounds on the generated randomness in terms of both min-entropy and von Neumann entropy in a device-independent scenario. Our results demonstrate the first experiment that certifies close to two bits of randomness from binary measurements of two parties. Apart from single-round certification, we provide an analysis of finite-key protocol for quantum randomness expansion using the Entropy Accumulation Theorem. Second, we present an efficient and practical method for certifying quantum randomness using generalized measurements. Indeed, we have derived a method for self-testing the presence of POVMs. We present the certification of more than one bit of min-entropy from a single POVM on one of the qubits of an entangled state using a variant of the elegant Bell inequality. We also obtain more than one bit of randomness in a prepare and measure scenario of a similar structure with a POVM on a single qubit. We provide numerical simulations to demonstrate the effectiveness of our randomness certification and expansion.
14:25-14:40	**David Fitzek**	Ind PhD student	Quantum computing theory	Chalmers	Routing Quantum Circuits with AlphaZero Deep Exploration	Compiling a quantum circuit for specific quantum hardware is a challenging problem, since current quantum processing units (QPUs) generally have low connectivity between physical qubits and limited coherence time. To make optimal use of these constrained resources and to ensure that the quantum circuit is executable on the target QPU, a circuit-transformation process with low depth overhead is essential. Due to the large search space for such circuit transformations, coupled with a high branching factor, the majority of existing algorithms tend to conduct only superficial searches, often resulting in solutions that are at best locally optimal. We propose an AlphaZero-inspired algorithm for systematically averting this limitation. Our method employs a transformer neural network in conjunction with deep lookahead in a guided tree search, which allows for searching deeper and attempting to find better solutions than existing algorithms do.